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Prevalence and Socio-Economic Factors Associated with Self-Injury Mortality: Differences in Vulnerability Across Racial Groups

Author
Mueller-Williams, Amelia Cromwell

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Prevalence and Socio-Economic Factors Associated with Self-Injury Mortality: Differences in Vulnerability Across Racial Groups

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Social Welfare

by

Amelia Cromwell Mueller-Williams

2023

ABSTRACT OF THE DISSERTATION

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by

Amelia Cromwell Mueller-Williams

Doctor of Philosophy in Social Welfare

University of California, Los Angeles, 2023

Professor Mark S. Kaplan, Chair

Suicide, alcohol, drug-related deaths, and deaths of undetermined intent are major contributors to racial/ethnic disparities in premature mortality in the United States. These causes can be studied as a composite measure, self-injury mortality (SIM). As a burgeoning concept, research using SIM holds promise to inform upstream prevention efforts that target multiple self-harm-related causes of death. Still, very little is known about how suspected social determinants are associated with SIM rates across racial groups. Related research suggests the socio-economic environment contains important factors influencing increasing mortality rates and racial disparities in SIM-related causes. Area-based deprivation is implicated as a good proxy measure for these factors, but no studies have investigated the links between multiple indicators of deprivation and SIM. Addressing gaps in existing research, this study assesses the relationship between state-year level Multidimensional Deprivation Index (MDI) and SIM rate in the U.S. population from 2015-2020 and among non-Hispanic American Indians/Alaska Natives, Blacks, and Whites. Data from National Violent Death Reporting System restricted access data provided information on suicides and deaths of undetermined intent, and among these deaths that were substance-involved. The cumulative annual percent change in SIM rates also increased over the study period markedly for Blacks, and to a lesser magnitude for AIANs, but not Whites. Among AIANs and Blacks SIM rate growth was primarily due to increases among youth and young adults. Results also indicated significant racial disparities in SIM rates overall, with AIANs bearing the highest burden of SIM risk, alcohol-related SIM, and SIM involving both alcohol and drugs. However, racial disparities were most prominent at low MDI levels, versus high MDI levels. Among the whole population, analyses found a dose-response effect of MDI on SIM rates, with the effect being significantly positive above mean levels of MDI. There was also significant variation in the effect of MDI on SIM across states. Overall, findings suggest that state socio-economic environment can potentially have a significant influence on SIM risk, especially in area with high levels of MDI. More research is needed to isolate the effect of specific socio-economic factors at multiple geographic levels, contextualize state environments within socio-economic policies, and elucidate specific pathways that may influence increasing SIM risk among AIAN and Black youth. This study provides evidence that prevention and intervention efforts targeting socio-economic factors could potentially mitigate population-level SIM risk, especially in states with high levels of multidimensional deprivation.

The dissertation of Amelia Cromwell Mueller-Williams is approved.

Daniel Eisenberg

Todd M. Franke

Sidra J. Goldman-Mellor

Mark S. Kaplan, Committee Chair

University of California, Los Angeles

2023

DEDICATION

This work is dedicated to those who have died by suicide, alcohol-, and drug-related deaths, and the communities that continue to suffer the heavy burden these losses.

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List of Acronyms

Term	Acronym
American Indian/Alaska Native	AIAN
Multilevel Deprivation Index	MDI
National Violent Death Reporting System	NVDRS
Self-Injury Mortality	SIM

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CURRICULUM VITA

2012 **M.S.W.**, University of Michigan, Ann Arbor
2012 **M.P.H.**, University of Michigan, Ann Arbor
2008 **B.A.**, Anthropology, Biology (double major), Macalester College, St. Paul, MN

PUBLICATIONS

Kaplan, M., **Mueller-Williams, A.C.**, Goldman-Mellor, S., Sakai-Bizmark, R. (2022). Changing trends in suicide and firearm involvement among Black emerging adults, 1999-2019. *Archives of suicide research*. doi.org/10.1080/13811118.2022.2098889

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SELECT PRESENTATIONS

Mueller-Williams, A.C. & Kaplan, M. (2022, Nov-Dec). Long-term Trends of Firearm suicide among American Indian and Alaska Native young adult men, 1999-2020. *National Research Conference on Firearm Injury Prevention, Washington, D.C.*

Mueller-Williams, A. C. (2021, May). *Factors Associated with County Racial/Ethnic Composition, Opioid Positivity, and Alcohol Intoxication among American Indian/Alaska Native Suicide Decedents, 2003-2015*. Population Association of America Annual Meeting, remote.

Mueller-Williams, A. C., Burrage, R.L., Hopson, J., Doria, C.M., Momper, S.L. (2021, January). *Gatekeeper Trainings in American Indian Communities: Increasing Knowledge and Feelings of Preparedness to Address Youth Suicide*. Society for Social Work Research Annual Meeting, remote.

Mueller-Williams, A. C., & Kaplan, M. S. (2018, November). *Sociodemographic and geographic patterns of alcohol-linked suicide among AI/ANs: Findings from the National Violent Death Reporting System*. American Public Health Association Annual Meeting, San Diego, CA.

Mueller-Williams, A. C. (2017, November). *Suicide morbidity and alcohol use among American Indian/Alaska Native and White young adults*. American Public Health Association Annual Meeting, Atlanta, GA.

SELECT RESEARCH EXPERIENCE

2022-2023 **Co-Investigator**, University of Hawai'i at Mānoa, Thompson School of Social Work & Public Health. Project title: Developing a Metatheory of Collective and Historical Trauma: A systematic review and qualitative synthesis. PI: Rachel Burrage, PhD.

2016-2017 **Graduate Student Research Assistant**, UCLA Department of Social Welfare. Grant title & funder: Economic Contraction and Alcohol-Related Suicides: A Multi-Level Analysis, National Institute on Alcohol Abuse and Alcoholism (R01-AA020063). PI: Mark S. Kaplan, DrPH.

2011-2015 **Research Associate/Grants Manager**, University of Michigan School of Social Work. Grant titles & funders: 1) Manidookewigashkibjigan - Sacred Bundle: RESPECT Project: 2 (Garrett Lee Smith State & Tribal Youth Suicide Prevention Grant), Substance Abuse & Mental Health Services Administration (SM-11-008). 2) CONNECTIONS: When We Work Together, Then We Are Wise Pii Maamwinokiyaang, Miidash Nibwaakaayaang (Systems of Care Implementation Grant), Substance Abuse & Mental Health Services Administration (SM-11- 001). 3) Manidookewigashkibjigan - Sacred Bundle: RESPECT Project (Garrett Lee Smith State & Tribal Youth Suicide Prevention Grant), Substance Abuse & Mental Health Services Administration (SM-12-003). 4) Nd'nibwaakaami - We are Wise: Sacred Bundle (Systems of Care Planning Grant for Expansion of the Comprehensive Community), Substance Abuse & Mental Health Services Administration (SM-14-008). 5) Detroit Urban Native Health Collaborative, Detroit Urban Research Center. 6) *Nd'nibwaakaami* - We are Wise: Sacred Bundle Pilot Grant, Detroit Urban Research Center. PI: Sandra Momper, PhD.

SELECT TEACHING EXPERIENCE

2018-2021 **Teaching Assistant/Associate**, UCLA Luskin School of Public Affairs, undergraduate program in Public Affairs, Master's program in Social Welfare.

2017-2020 **Adjunct Lecturer**, California State University—Los Angeles, Rongxiang Xu College of Health and Human Services. Courses: Childhood & Adolescence (Fall, Spring 2017-2020); American Indian Families (Spring 2020).

CHAPTER 1: INTRODUCTION

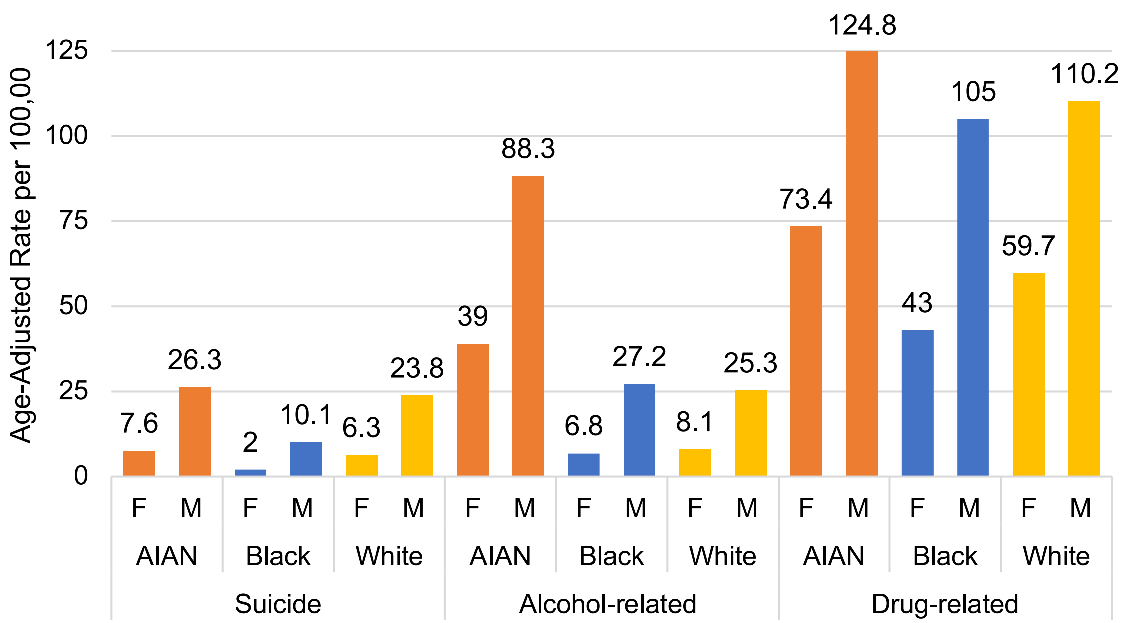
For the first time in a century, the United States is experiencing significant absolute declines in life expectancy, beginning after 2014 (Crimmins & Zhang, 2019; Kochanek et al., 2019). This health phenomenon is unique among high-income countries and has been driven by increases in all-cause mortality rates among American adults ages 25-64 since 2010 (Avendano & Kawachi, 2014; Crimmins & Zhang, 2019; Woolf & Schoomaker, 2019; Shiels et al., 2020). A recent consensus report from National Academy of Sciences reviewed the body of literature related increasing mortality and decreasing life expectancy in the working-age U.S. population (National Academies of Sciences [NAS], 2021). The report solidifies previous findings on cause-specific mortality, indicating that contemporary population health is driven primarily by three trends 1) increases in suicide, 2) increases in alcohol- and drug-related deaths, and 3) slowing declines in cardiometabolic disease (Case & Deaton, 2015, 2017; Crimmins & Zhang, 2019; Muennig et al., 2018; NAS, 2021; Shiels et al., 2020; Woolf et al., 2018; Woolf & Schoomaker, 2019NAP, 2021). These findings underscore the urgent need for research to address factors associated with suicide, alcohol-, and drug related death.

Temporal trends suggest that mortality rate increases have unfolded over approximately the last 50 years for different causes and demographic subgroups. Beginning in the 1970s, mortality rates due to drug overdose began increasing exponentially (Woolf et al., 2018). Over the next decade, U.S. life expectancy gains began to stagnate compared to other countries; by the 1990s continued increases in drug-related mortality rates exacerbated geographic patterns in life expectancy (Shiels et al., 2020; Woolf & Schoomaker, 2019). Suicide and alcohol-related mortality followed, beginning to increase in 2000 (Shiels et al., 2020; U.S. Congress Joint Economic Committee, 2019; Woolf & Schoomaker, 2019).

Suicide, alcohol-, and drug-related mortality are also unequally distributed across race/ethnicity and sex. Overall rates are substantially higher for males and among non-Hispanic American Indian/Alaska Native (AI/AN) populations and non-Hispanic Whites (Whites) compared to non-Hispanic Blacks (Blacks) and other races (Hedegaard et al., 2018; CDC, 2019; WHO, 2014). High and rising rates of these causes of death contribute to disparities in health outcomes between racial groups (Case & Deaton, 2017; Rockett et al., 2020; Shiels et al., 2020; Woolf & Schoomaker, 2019).

Recent data show suicide, alcohol-, and drug-related mortality rates are increasing for all groups of working-age adults since 2017, but the magnitude, trajectory, and timing of the increase differs across race and causes of death (Figure 1) (NAS, 2021; Shiels et al., 2020; Woolf & Schoomaker, 2019). For AI/ANs, overall mortality rates have been increasing for each birth cohort since 1948, reflecting a general pattern of poorer health among Indigenous peoples. Beginning around the year 2000, suicide, alcohol-, and drug-related mortality began growing for both AI/ANs and Whites (Shiels et al., 2017; Woolf et al., 2018). For Blacks, the timing of mortality rate increases differs by cause, beginning around 2010 for drug deaths, 2012 for alcohol deaths, and 2015 for suicide (Shiels et al. 2017; Shiels et al., 2020; Woolf et al., 2018; Woolf & Schoomaker, 2019).

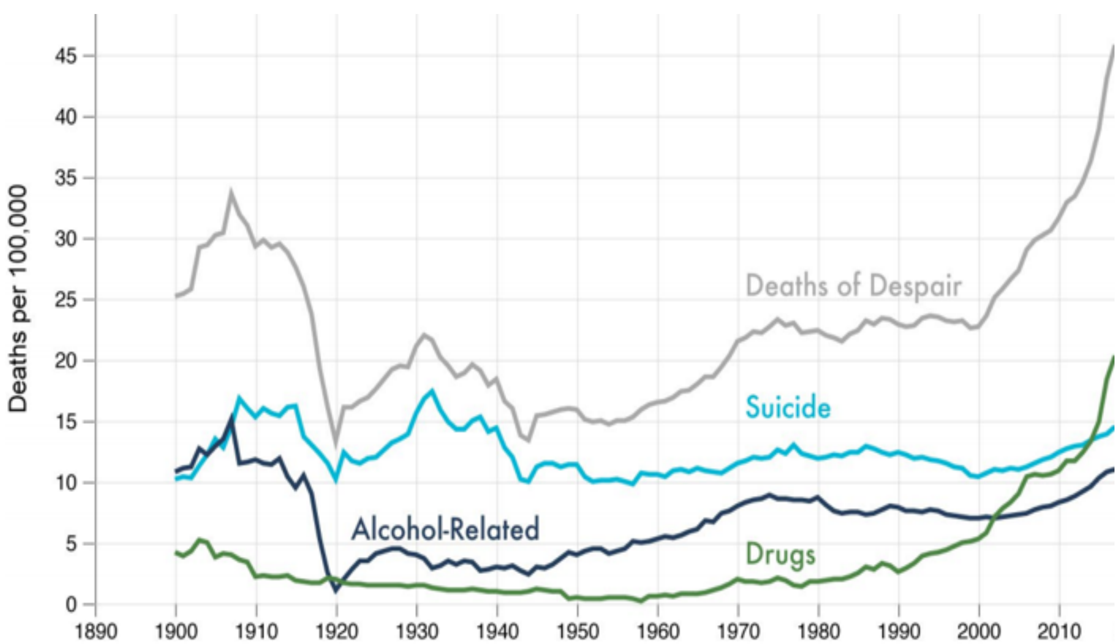
Figure 1. Suicide, Alcohol-, Drug-related Mortality Rates by Race and Sex, 1999-2019.



Source: CDC WONDER, 2021

From the observation that trends in suicide, alcohol-, and drug-related mortality rates seem to move together emerged new frameworks proposing that these causes of death may share a common cause or could be studied as a group (Case & Deaton 2015, 2017; Rockett, 2014, 2016). The common cause approach appears in the literature established by Case & Deaton (2015, 2017) and refers to these causes of death as “deaths of despair”; Rockett et al. (2016) suggest using the term self-injury mortality (SIM). Whereas “deaths of despair” groups all suicide, alcohol-, and drug-related causes, theoretically, SIM includes suicides, unintentional drug-related deaths, and deaths of undetermined intent (Case & Deaton, 2015; Rockett et al., 2016). In their “deaths of despair” argument, Case & Deaton hypothesize that mortality trends are “likely symptoms of the same underlying epidemic” that increases vulnerability to suicide, alcohol-, and drug-related causes of death among populations with accumulated exposure to latent socio-economic risk factors (2015; p. 15081). The SIM concept does not posit that latent variables link these deaths, but groups the causes based on their shared nature as outcomes resulting from acute self-injurious behaviors that share multiple antecedent risk factors.

Figure 2. Deaths of Despair & Cause of Death Components, 1900-2017.



U.S. Congress Joint Economic Committee, 2019

Both “deaths of despair” and SIM are useful to improve our understanding trends in premature mortality due to self-injurious acts. SIM provides a conceptual and evidence-based measurable outcome to test, while “deaths of despair” provides a social determinants of health-based framework with which SIM can be studied empirically and contextualized within the broader socio-economic environment. SIM is a more reasonable measure of mortality than “deaths of despair” because it avoids the significant barriers presented by including chronic alcohol-related deaths (e.g., alcoholic liver disease) that have a long latency period between exposure and death. It also addresses the substantial misclassification of drug-related deaths as accidental or undetermined intent that leads to an underestimation of suicide rates (Bohnert et al., 2013; Choi et al., 2019; Lachaud et al., 2018; Rockett et al., 2016; Rockett et al., 2020).

The use of SIM is especially appropriate in the context of the opioid epidemic, which fuels substantial year-to-year increases in drug-related deaths and deaths of undetermined intent (Bohnert & Ilgen, 2019; Shiels et al., 2017). Using SIM to frame temporal trends in suicide, alcohol-, and drug-related mortality helps explain why mortality rates began increasing in different years across race groups. For example, drug overdose rates during the 1980s-1990s crack cocaine epidemic heavily impacted Blacks, and prescription opioid-related deaths in the 2000s were more prevalent among AI/ANs and Whites before the epidemic spread (Dasgupta et al., 2018; Plunk et al., 2018; Tipps et al., 2018). Simultaneously, accidental and undetermined intent deaths were significant contributors to overall mortality among AI/ANs, Blacks, and White women, paralleling trends associated with the opioid epidemic (Bohnert & Ilgen, 2019; Shiels et al., 2017).

This pattern in SIM highlights the critical role of environmental characteristics, which are integral to explaining racial differences in health. AI/ANs and Blacks experience the highest overall mortality rates in the U.S., stemming from enduring health disparities and structural inequities that are likely determinants of SIM and other causes of premature mortality

(Braveman et al., 2011; Shiels, 2017; Woolf & Schoomaker, 2019; Williams et al., 2019). As structural determinants of health are implicated in racial disparities in premature mortality, researchers look to the socio-economic environment to identify potential social determinants of increasing SIM rates.

The relatively recent introduction of SIM and “deaths of despair” into the literature has ignited an overdue need to widen our lens to consider the dynamic relationship between socio-economic contexts and SIM-related outcomes. Relevant literature, especially in suicidology, is dominated by reductionist approaches that conceptualize suicide and self-injurious behaviors as fundamentally individual, psychologically-based issues that should be addressed via individual-level interventions (Klonsky et al., 2016; Marsh, 2020). However, the culmination of extant research shows that individual risk factors poorly predict self-injurious behaviors like suicide (Hjelmeland & Knizek, 2017; Klonsky et al., 2016; Nock et al., 2019).

Population approaches to SIM are needed to guide future research. They provide good opportunities to account for within and between-group heterogeneity—including more holistic understandings of racial disparities (Alcántara & Gone, 2008; Asarnow & Ougrin, 2019; Fuhrer & Keyes, 2019; Galea & Keyes, 2018; Nock et al., 2018; Wexler et al., 2015). Theoretical models that incorporate race into conceptual pathways between socio-economic environments and health, such as the social determinants of health, are especially useful (Braveman et al., 2011; Pickett & Wilkinson, 2015). For example, the socio-economic patterning of SIM-related deaths across groups may offer some clues to understanding how the socio-economic context may operate differently across groups (Diez-Roux, 2017; Rockett et al., 2016).

Case & Deaton (2015, 2017) observed that changes in the U.S. socio-economic environment coincided with increases in "deaths of despair." As premature mortality rates increased, research documents changes related to globalization, technological change, neoliberal policy orientation, austerity, and economic stagnation, and shifts in the social environment, including changes in social support, family structure, and decreasing psychological well-being (Case & Deaton 2017; Gaydosh et al., 2018; Muennig et al., 2018). Yet, few studies other than Case & Deaton (2017) incorporate multidimensional measures of the socio-economic context into empirical work on “deaths of despair” or SIM. Available research shows geographic patterning of socio-economic indicators and SIM rates, further pointing to a need for contextualized inquiry (Case & Deaton, 2017; Monnat, 2018; Shiels et al., 2020).

Significantly, Case & Deaton's (2017) work contributes a framework for investigating the link between SIM and the socio-economic environment. Using the idea that multilevel experiences of “despair” characterize changes in the socio-economic environment and their effect on human experiences, Case & Deaton (2017) model mortality rates and deprivation indicators as measures of “despair” among Whites and Blacks in mid-life. From their findings, they suggest that these risk factors concentrate vulnerability among “disadvantaged” White populations, particularly those with less than a college education, in a process of longitudinal downward mobility (Case & Deaton, 2015, 2017, 2020).

This originating body of work on “deaths of despair” piqued national interest and inspired subsequent investigations linking environmental characteristics to premature mortality rates under Case & Deaton’s hypothesis (e.g., Blacksher, 2018; Cherlin, 2018; Masters et al., 2018; Meit et al., 2019; Shiels et al., 2017; Siddiqi et al., 2019; Stein et al., 2017; Scutchfield, 2019; Squires & Blumenthal, 2016; Zarroli, 2020). Altogether, the current body of “deaths of despair” research suggests that the largest relative increases in SIM-related causes have occurred among people with less education and in areas experiencing diminished socio-economic resources and opportunities (Case & Deaton, 2015, 2017; Knapp et al., 2019; Monnat 2018; Woolf & Schoomaker, 2019). However, this literature lacks cohesiveness and has spurred significant criticism from the scholars and media, which often critique the focus on Whites and the validity of combining suicide, alcohol-, and drug-related causes of death into a composite measure (Boyd, 2020; Diez-Roux, 2017; Guo, 2017; Masters et al., 2018; Muennig et al., 2018; Shanahan et al., 2019). Another major limitation highlighted by researchers is the “deaths of despair" literature's overemphasis on economic factors. Influenced by a vague conceptual model for understanding which aspects of the economy are related to "deaths of despair," studies estimating the effect of economic environments utilize different measures and produce mixed results. Specifically, research finds inconsistent relationships between various economic indicators across suicide, alcohol, and drug-related deaths (Bradford & Bradford, 2020; Gutin & Hummer, 2020; Knapp et al., 2019; Rhum, 2018).

Strategies to address these limitations are available. As presented by Case & Deaton (2017), the concept of deprivation holds promise in addressing the need for measures that meaningfully incorporate economic *and* social factors (Diez-Roux, 2017; Gutin & Hummer, 2020; Rhum, 2018; Shanahan, 2019; Venkataramani & Tsai, 2020). Utilizing SIM accounts for the misclassification of intent, which may bias cause-specific associations; it also allows for the exploration of economic factors that are found to be related to both suicide and drug-related deaths (e.g., eviction rates, financial strain) but not alcohol-related chronic diseases (Bradford & Bradford, 2020; Case & Deaton 2017; Elbogen et al., 2020; Gutin & Hummer, 2020; Fowler et al., 2015; Prins et al., 2018; Rudolph et al., 2020). Alcohol use behaviors such as heavy drinking can be incorporated into SIM when they occur proximally to death; thus, factors related to SIM and acute alcohol use (e.g., employment, local labor market characteristics) can also be investigated (Case & Deaton 2017; Gutin & Hummer, 2020; Hawkins et al., 2020; Prins et al., 2018). Relevant studies on suicide and drug-related outcomes find that for some economic indicators (e.g., unemployment), associations vary by race, sex, and community characteristics (Frankenfield & Leslie, 2019; Kaufman et al., 2020; Rudolph et al., 2020). Using SIM helps adjust for racial biases in unintentional death classifications and may provide a more accurate sample to estimate the impact of socio-economic factors on premature mortality within and between subgroups.

Findings from the "deaths of despair" literature generates a narrative around racial health disparities that challenges traditional thinking on how race-based social hierarchy influences cause-specific mortality (Plunk et al., 2018; Brown & Tucker-Seeley, 2018). Higher SIM-related death rates are found among less-educated Whites—a relatively privileged demographic group traditionally thought to be protected against systematic disadvantage. Despite relatively similar experiences with structural violence and oppression generally associated with higher mortality risks, SIM among AI/ANs and Blacks trend in opposite directions, higher and lower, respectively. This racial pattering in SIM outcomes calls for contextualized inquiry that thoughtfully considers the unique circumstances in which these populations live (Gone et al., 2019; Jackman & Shauman 2019; Wexler et al., 2015; Williams et al., 2019;). However, extant literature investigating these causes of death together emphasizes the burden among "disadvantaged" Whites and fails to meaningfully apply race in the context of enduring structural inequalities in socio-economic opportunities (Case & Deaton 2015, 2017; Masters et al., 2017; Shiels et al., 2020; Stein et al., 2017; Woolf & Schoomaker, 2019). The resulting gap in literature represents a significant lack of understanding of the differential impact of socio-economic conditions on the racial patterning of SIM.

CHAPTER 2: RESEARCH FOUNDATION

This chapter provides a more detailed review of the social epidemiology of SIM, including a review of relevant literature. This section reviews statistics on SIM-related deaths, the justification for using SIM in research, and situates SIM within the context of the “deaths of despair” framework. The chapter concludes with a description of gaps in the literature and the specific aims of this study that address these gaps.

Background Literature

SIM-related deaths warrant attention as they differentially impact subgroups of the U.S. population and are meaningfully preventable (Harper et al., 2020; Kochanek et al., 2019; Shiels et al., 2020; Woolf & Schoomaker, 2019). Additionally, the opioid epidemic has amplified concern for the potential underestimation of suicide deaths involving drugs, necessitating an additional focus on deaths of undetermined intent. In the absence of clear evidence demonstrating suicidal intent, such as a suicide note, drug-related deaths may, by default, be classified as “accidental” or of “undetermined indent” (Choi et al., 2019; Rockett et al., 2016). Research on these causes finds that misclassifying drug-related deaths as accidental or undetermined leads to the underestimation of suicide rates (Bohnert et al., 2013; Lachaud et al., 2017; Rockett et al., 2016, 2020). Further, studies find that the risk for misclassification differs across race and state, suggesting a racial bias among authorities assigning intentionality to drug-related deaths (Choi et al., 2019; Rockett et al., 2016). Decomposing SIM-related causes (i.e., deaths due to undetermined intent, suicide, alcohol, and drugs) shows variation across racial groups representing a significant threat to racial health equity (Table 1; CDC, 2020b).

Table 1. Age-Adjusted Mortality Rates per 100,000 population, 2010-2018.

	Cause of death			
Race (non-Hispanic)	**Suicide**	**Alcohol-Related**	**Drug-Related**	**Undetermined Intent**
AIAN	19.2	84.1	20.5	3.4
Black	6.1	16.9	12.9	1.9
White	16.5	20.9	18.3	2.0
Total	14.3	19.7	16.1	1.8

CDC WONDER Multiple Cause of Death files. ICD-10 codes used for suicide (X60-X84), alcohol-related (A1, A9), drug-related (X40-X44), and undetermined intent (Y10-Y34, Y87.2).

For all-cause mortality, baseline rates are highest among AI/ANs and Blacks, reflecting reflect historically-rooted structural inequities and experiences of oppression; for SIM, baseline rates are highest for AI/ANs followed by Whites and Blacks (Shiels et al., 2020; Woolf et al., 2018; Woolf & Schoomaker, 2019). These causes of death have a larger negative impact on life expectancy for AI/ANs and Whites compared to Blacks; overall life expectancy is lowest for AI/ANs (73.0 years) and Blacks (74.8 years), compared to Whites (78.5 years) (CDC, 2017; Indian Health Service, 2015; Shiels et al., 2020; Woolf & Schoomaker, 2018).

Research using data up to 2015 suggested that premature mortality only significantly affected Whites and AI/ANs, not Blacks (Case & Deaton, 2015, 2017; Shiels et al., 2018; Stein et al., 2017). However, more recent data show that this trend has changed. Since 2017 Blacks are also experiencing increasing premature mortality and decreases in life expectancy associated with self-injury (Shiels et al., 2020; Woolf & Schoomaker, 2019). Research finds that from 1999-2016 SIM-related midlife mortality rates have increased for most racial groups (Table 2; Woolf et al., 2018) (Shiels et al., 2020; Woolf & Schoomaker, 2019).

Table 2. Percent Change in Midlife Mortality Rates Across Racial Groups from 1999-2016 (Woolf et al., 2018).

Race (non-Hispanic)	**Suicide**	**Alcoholic Liver Disease**	**Alcohol Poisoning**	**Drug Overdose**
AIAN	91.2%	65.9%	366.6%	411.4%
Black	13.7%	242.0%	−31.59%	149.6%
White	49.4%	62.4%	674.5%	494.3%

For suicide specifically, the largest rate increases across demographic groups from 1999-2017 were among AIANs, females (139%) and males (71%) (Hedegaard et al., 2018). Relatively little research meaningfully includes AIAN groups. Only three population-level studies including suicide, alcohol- and drug-related deaths have evaluated the impact among AIANs; only one study of undetermined deaths has included an AIAN sample (Shiels et al., 2020; Woolf et al., 2018; Woolf & Schoomaker, 2019). Furthermore, little research demonstrates interest in contributing knowledge to understanding racial differences in SIM. This results in a limited understanding of the social etiology of mortality rate differences across groups and, subsequently, barriers to effective prevention efforts.

Outcome Measures of Mortality: Essential to Consider in the Case of Self-Injury

Using valid and reliable mortality measures is critical to generating accurate epidemiological profiles across groups. SIM (i.e., suicide, drug-related, and undetermined intent deaths) and "deaths of despair" (i.e., all suicide, alcohol-, and drug-related deaths) are the two dominant approaches to operationalizing a composite measure of self-injury causes (Case & Deaton, 2015, 2017, 2020; Rockett, 2016, 2020). The SIM and "deaths of despair" approaches differ in reasoning for including specific causes of death and threats to validity when operationalizing a mortality measure. However, both propose composite measures based on the factor that unifies these causes of death—they are all attributable to self-directed injurious behaviors.

Deaths due to undetermined intent, suicide, alcohol, and drugs are logically linked through common risk factors, suggesting a shared etiology. This link is supported by clinical and epidemiological research, which suggests that the presence of mental illness and substance abuse can exacerbate each condition bidirectionally and intensify the risk of suicide; though some research suggests the relationship between drug overdose and suicide may not be multiplicative, underscoring the lethality of opioids as a primary driver of mortality (Arias et al., 2016; Esang & Ahmed, 2018; Olfson, Schoenbaum & Goldman-Mellor 2020; SAMHSA, 2016; Wilcox et al., 2004; Yuodelis-Flores & Ries, 2015). Substance use disorders are associated with a 10-14 times higher risk of suicide compared to the general population, with especially potent effects among those with alcohol and opioid use disorders (Esang & Ahmed, 2018; SAMHSA, 2016; Wilcox et al., 2004; Yuodelis-Flores & Ries, 2015).

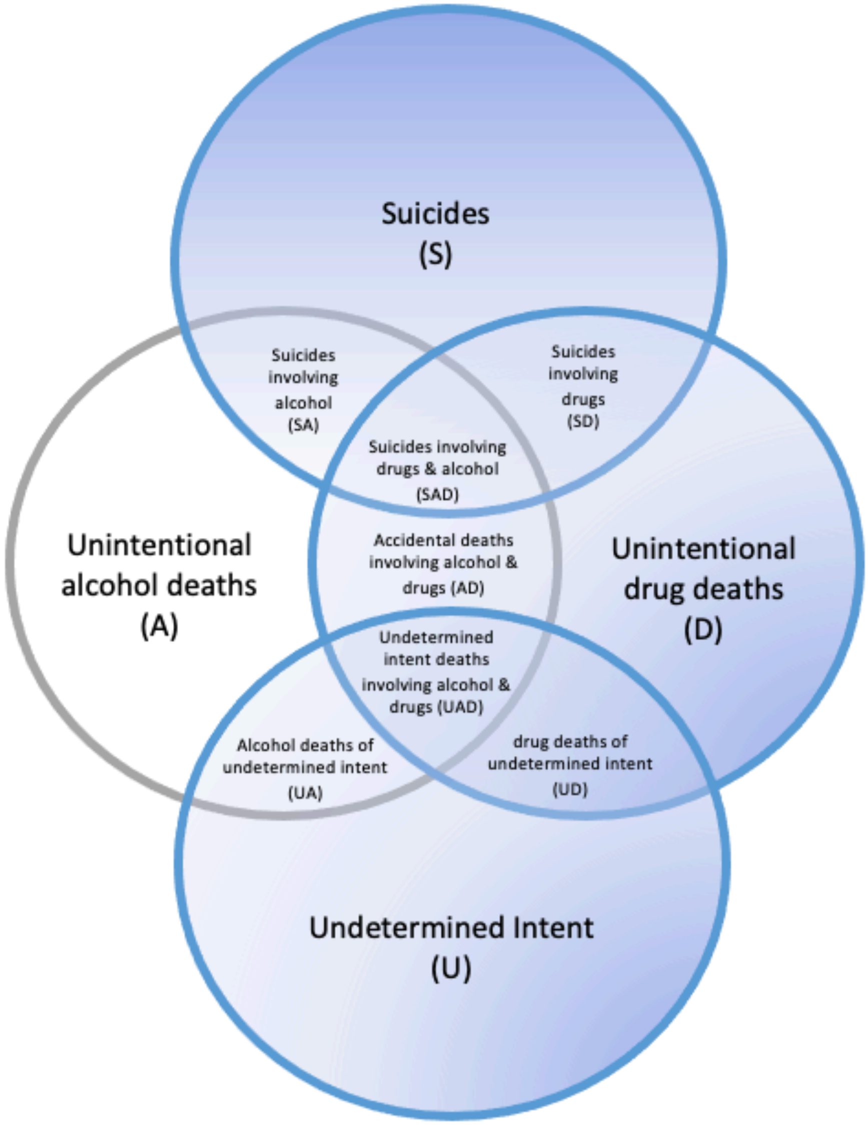
When approached as independent causes, these types of mortality can be challenging to study empirically. Suicide, alcohol-, and drug-related deaths can meaningfully overlap (e.g., alcohol- and drug-related suicides, deaths of undetermined intent) and represent competing risks. This limits our ability to estimate their lethality and quantify the effect of social determinants, which are essential for effective prevention and intervention efforts. Population-level aggregation presents another challenge by masking potential differences in compositional mortality and between-group disparities in outcomes.

Overall, studies of SIM-related deaths can consider causes as discrete or composite events at an individual level, regardless of assigned intent. The SIM concept includes a large portion of where these causes of death occur independently and where they overlap (Figure 3). When studying these types of mortality, research must appropriately attend to the essential similarities and differences in the manifestation of these causes of death within individuals and populations. For example, patterns of suicidality and drug use are more consistent. Both have high-risk behaviors (i.e., suicidal ideation, plans, risky drug use) associated with serious non-fatal injury (i.e., suicide attempt and overdose) or death. Yet, for every suicide and drug overdose fatality, there are far more instances of high-risk behavior or injury that do not result in death (Klonsky et al., 2016; Olfson et al., 2018; Owens, 2002; Suffoletto & Zeigler, 2020). Suicide and substance misuse/substance use disorders co-occur at a high rate at the individual and population levels. They are also mutually reinforcing risk factors to the point where the differentiation between suicidality and overdose risk may be clinically significant but without a meaningful interpretation at an ecological level.

There is no significant latency period between behavior and death for suicides and drug-related deaths. In contrast, alcohol-related problems are highly skewed towards morbidity versus mortality. Generally, heavy alcohol use requires prolonged exposure to cause death; however, it is causally associated with many causes of death directly and indirectly (CDC, 2020a; Shield et al., 2014). For example, excessive alcohol use can cause alcoholic liver disease and short-term health risks such as fatal accidents, poisoning, and other chronic diseases like hypertension (Shield et al., 2014). Simply, alcohol use is less acutely fatal than suicide attempts or drug overdoses but can kill through a broad range of associated diseases.

Because suicide and drug-related deaths occur quickly, they offer the best opportunity to identify pathways between vulnerability factors and mortality. However, some alcohol-related deaths that share characteristics of suicides and drug overdoses may be reasonably grouped within the SIM outcome when they share certain characteristics, for example, when they reflect concurrent or acute alcohol use behaviors (e.g., heavy drinking or intoxication) or death caused by alcohol overdose. This approach to including alcohol-related deaths is important because it allows for studying causes of death that meaningfully overlap with suicide.

Figure 3. Individual and Common Causes of Death due to Undetermined Intent, Suicide, Alcohol- and Drug-related Causes (SIM Causes Highlighted in Blue).



A specific focus on the overlap between substance use and suicide is also justified. Studies show acute alcohol intoxication and drug use are strongly associated with suicide and differ across race and sex. An estimated 30-40% of suicide attempts involve alcohol (Cherpitel et al., 2004). Results from a large sample of suicide decedents found that alcohol use before death occurred in 47% of AIANs, 26% of Blacks, and 33% of Whites (Caetano et al., 2013). Further investigations also suggest suicide decedents have an elevated risk for heavy alcohol use before death (i.e., legal intoxication) compared to a living sample, and that risk differs significantly across race/ethnicity and sex (Caetano et al., 2015; Kaplan et al., 2016).

There is also a significant link between suicide and drugs, especially opioids; however, the body of empirical literature investigating drug-related suicides is significantly smaller than for alcohol-related suicides. Recent surveillance data shows opioids are involved in an estimated 27.5% of suicide deaths; among opioid overdose deaths, 7.2% are suicides, 87.4% are unintentional, 5.2% are undetermined intent (CDC, 2021; Hedegaard et al., 2020). One report that considered drug-related suicide rates across racial groups found that AIANs were significantly less likely to screen positive for opioids than their White counterparts (Leavitt et al., 2018). More descriptive and empirical evidence is needed to reconcile racial differences in suicide, opioid, and opioid-related suicide rates.

Self-Injury Mortality: A Robust Measurable Outcome

Case & Deaton's approach to studying SIM-related deaths leaves the operationalization of "deaths of despair" open for interpretation, with some different cause of death classifications included across studies. For example, the alcohol component of "deaths of despair" sometimes includes only alcoholic liver disease. Other times includes a broad range of alcohol-attributable deaths (e.g., Case & Deaton, 2015; Shiels et al., 2020). The SIM measure is based on conceptual and empirical reasoning and should be preferred over "deaths of despair" in research investigating these causes of death. This section includes a review of the conceptual and empirical justification for using SIM.

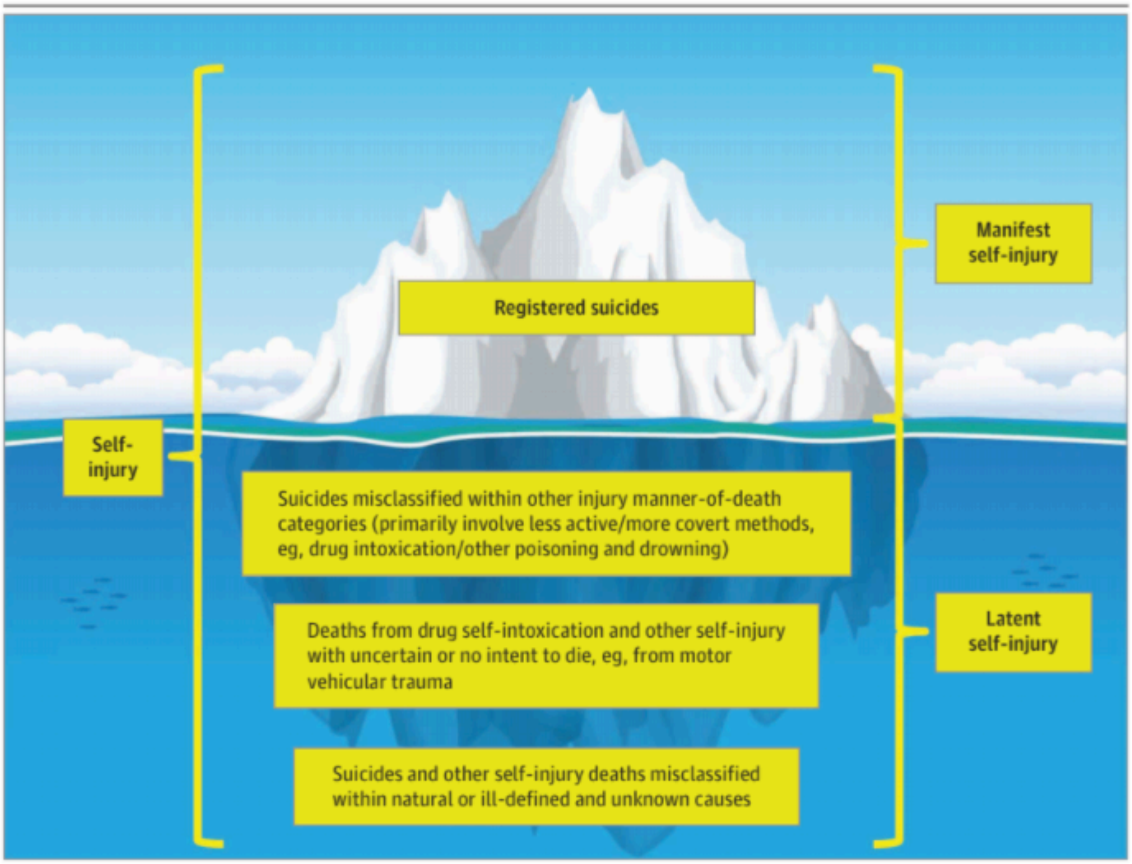
The originators of SIM argue that the barriers between most SIM-related cause classifications (i.e., undetermined indent, suicide, alcohol-, and drug-related deaths) are artificial, unreliable, and strict application can hinder intervention and prevention efforts by limiting the ability to target upstream determinants that could address multiple causes of SIM that also frequently overlap (Rockett, 2016, 2020). The SIM approach emphasizes prevention as the most practical and meaningful way to address mortality risk. As Rockett and colleagues (2022) themselves describe:

> SIM augments registered suicides with most opioid or other drug overdose fatalities caused by individuals' instrumental actions on the day of death—ultimately with the goal of improving injury surveillance, enhancing etiologic understanding, and establishing the foundation for effective, scalable programs of prevention and clinical intervention. We have applied the broader construct of SIM to characterize drug fatalities arising from persons' instrumental behaviors, given well-documented uncertainty of where to draw demarcating lines between deaths arising from an intention to die (ie, suicides), intentional behaviors that lead to fatalities (i.e., drug-related deaths now called accidents, later relabeled unintentional by the Centers for Disease Control and Prevention) as diagnosed by medical examiners or ruled by coroners , as well as truly accidental or unintentional injuries that occur without preceding probability-altering risk factors (p.2).

This reasoning aligns with some views from suicide-specific literature arguing that research should focus on prevention because, as Alcántara & Gone note, "paradoxically, any 'treatment' for suicide must necessarily occur before the act itself" (2008, p. 459).

Evidence supports the grouping of undetermined intent deaths with those attributed to suicide and drugs. Suicide risk is high among individuals who misuse substances, especially opioids, and a significant portion of drug-related deaths of undetermined intent may be intentional but classified as accidents or undetermined intent (Choi et al., 2019; Rockett et al., 2016, 2020; Kelly et al., 2022; Connery et al., 2022; Na et al., 2022). Research suggests that suicidality among opioid users should be considered on a spectrum, where many individuals endorse some desire to die, with or out without the intent to die as the result of their drug use at a given moment in time (Kelly et al., 2020; Connery et al., 2022). As a result, clinical and public health practice has begun to strongly push towards considering the high risk of suicide or self-harming behaviors (e.g., overdose) associated with experiencing multiple psychosocial problems (multimorbidity) in clinical settings and the population-level overlap between drug overdose and suicide (Bhalla & Rosenheck, 2018; Na et al., 2022; Thombs, 2020; Rocket et al., 2022). Indeed, authors have described "deaths of despair" as only the tip of the iceberg; what lies beneath is a high burden of individual's daily suffering from diseases of despair and antecedents to SIM (Rockett et al., 2016; Na et al., 2022). Figure 4 from Rockett et al. (2016) describes how measures of suicide deaths alone underestimate the burden of self-injurious behavior (p.1079).

Figure 4. Suicide and Latent Self-Injury Mortality (Not to Scale).



Source: Rockett et al., 2016, p. 1079

Conceptualizing undetermined intent, suicide, alcohol-, and drug-related mortality as SIM may be a more valid way of reflecting the phenomenon, especially for prevention purposes (Bohnert et al., 2013; Choi et al., 2019; Rockett et al., 2016; Rockett et al., 2020). Considering the multiple, overlapping dimensions of SIM deaths and shared antecedent factors, using SIM in research will likely help identify intervention points relevant to multiple social determinants of premature mortality.

SIM has several additional strengths. It avoids empirical barriers posed by including alcohol-related deaths that have a long latency period and addresses significant issues with misclassification of intent among drug-related deaths that differentially impact socio-demographic subgroups (Rockett, 2020). Patterns in mortality rates by race are supplemented by examining deaths of undetermined intent. Especially for drug overdose deaths, misclassification as undetermined intent versus suicide is associated with race/ethnicity, with higher rates of undetermined deaths found among women and Blacks compared to Whites (Choi et al., 2019; Rockett et al., 2016). Despite high rates of drug-related deaths among AIANs, there is a paucity of research on cause of death misclassification in this group (Mack et al., 2017; Tipps et al., 2018). However, existing data on mortality trends suggest an association between suicide, the opioid epidemic, and unintentional and accidental deaths—all major contributors to overall premature mortality among AIANs, Blacks, and White women (Bohnert & Ilgen, 2019; Shiels et al., 2017).

SIM provides the best option for empirical studies of mortality due to self-injurious behaviors. Because the SIM perspective considers cause of death classification boundaries flexible, it implies that useful conclusions can be drawn from examinations of overlapping causes of death. Contrasts between undetermined deaths, non-substance suicides, and alcohol- and drug-related suicide offer a unique opportunity to generate knowledge on the interplay between suicide, alcohol, and drug use that could illuminate essential points for both targeted interventions and population-based prevention efforts.

“Deaths of Despair” A Framework for Contextualized Inquiry

> *“Together with other colleagues, we have advocated the use of ‘self-injury mortality’ (SIM) to mitigate the uncertainties of injury manner of death determinations, while underscoring the collective public health importance of intervening long before people come to the ‘edge of the ledge’. Case and Deaton encompass SIM within their ‘deaths of despair,’ and emphasize the tragic economic circumstances that often contribute to the contextual underpinnings of recent decreases in US life expectancy.”*
> – Rockett et al., 2021

As outlined above, producing a valid measurable mortality outcome is not the strength of the “deaths of despair” approach; the SIM measure is the more robust choice. However, SIM does not provide a model to guide studies that use it. The most significant contribution of Case

& Deaton's work is the framework it provides to examine SIM-related causes that consider the socio-economic circumstances in which people live. The following discussion describes and evaluates the usefulness of the "deaths of despair" framework in studying SIM.

Case & Deaton developed the foundational knowledge for the "deaths of despair" conceptual model to link changes in the socio-economic environment beginning around 1980 to increases in SIM rates. To test their hypothesis, they used mortality data on non-Hispanic Black and White Americans in midlife to model socio-economic deprivation indicators on SIM-related deaths by each successive birth cohort after 1940 when they entered the labor market (2017). The results suggest that deprivation measures positively correlate with one or two latent drivers of SIM rates. Furthermore, their findings on race and education level differences purposefully emphasize a high burden of SIM concentrated in middle age Whites with less than a college degree. Overall, Case & Deaton (2017) offer a common cause interpretation, hypothesizing macro-level socio-economic changes and rising SIM-related mortality are "likely symptoms of the same underlying epidemic," the latent factor which they generally refer to as "despair" (2015 p.15081, 2017, 2020). The differential burden experienced across socio-demographic subgroups, then, is associated with the accumulation of risk factors and heightened "despair." In the context of a changing socio-economic environment that no longer offers the same protections, privileges, and opportunities available to previous generations, Case & Deaton (2017, 2020) attribute the increased vulnerability to SIM among less-educated Whites to cumulative disadvantage acquired in the process of long-term downward socio-economic mobility (Case & Deaton, 2017, 2020).

Recent research comparing "deaths of despair" trends in the U.S. to those of analogous countries not found similar trends in the European context, suggesting the high and increasing rates are specific to the U.S. social and political landscape (King, Scheiring, & Nosrati, 2022; Lange et al., 2022; Caine, 2022). This supports the "deaths of despair" framework's implication of economic factors (e.g., globalization, neoliberal policy orientation, austerity, economic stagnation) and social factors (e.g., disintegration of traditional social support, social capital, decreases in psychological well-being) as primary drivers. Researchers have also begun to highlight how the current circumstances of “deaths of despair” echoes the impact of rapid socioeconomic change due to deindustrialization on drug use in urban Black communities in the 1990s, primarily through the work of William Julius Wilson (King, Scheiring, & Nosrati, 2022; Monnat, 2018; Kubrin, 2006; Case & Deaton, 2017; Cerdá et al., 2021). With previous theoretical and empirical precedence demonstrating the impact of upstream factors on SIM-related outcomes, the multidisciplinary and governmental embrace of the “deaths of despair” framework represents a critical shift in theoretical orientation, away from traditional approaches to self-injury that emphasize individual-level and psychological antecedents. This wider-lens approach provides a model for research to investigate the social determinants of SIM-related mortality.

However, Case & Deaton do not propose specific social or economic definitions for the latent variables implicated in "deaths of despair." They also do not offer a comprehensive conceptual model. As a result, scholars highlighted the challenges of incorporating the "deaths of despair" framework into empirical research (Diez-Roux, 2017; Muennig et al., 2018; Rhum, 2018; Shanahan et al., 2019). In response, Shanahan et al. (2019) offered the first conceptual mapping of deaths of despair, building a theoretical foundation for future research focused on testing pathways from the socio-economic environment to SIM-related deaths (see Appendix A for the conceptual model).

“Deaths of despair” has injected a much-needed focus on the social determinants of SIM. It utilizes an approach that is grounded in the social determinants of health (SDOH) perspective, which establishes a conceptual pathway between social and economic environments and health (Braveman et al., 2011; Pickett & Wilkinson, 2015; Solar & Irwin, 2010; see Appendix A for the SDOH conceptual model). Using the “deaths of despair” model to study

SIM helps frame investigations into how observed differences in social epidemiological profiles for SIM are related to the differential distribution of resources and opportunities across groups.

Individual-level Studies Using the "Deaths of Despair" Framework

The conceptual ambiguity of the "deaths of despair" framework makes it adaptable but is also a major point of criticism. Researchers critique how the "despair" construct is used in the literature without being assigned a meaning or demonstrating ways to operationalize it in research. The general consensus is that "deaths of despair" is an underdeveloped research area that uses a generalized definition grounded in hopelessness and inability to cope (King, Scheiring, & Nosrati, 2022). Only recently have studies started to test this idea. "Despair" as a construct is most familiar at the individual-level, logically related to mental health (e.g., depressive symptoms). Indeed, psychologically-based interpretations suggest despair can manifest in cognitive, emotional, behavioral, and biological domains (Copeland et al., 2020; Shanahan et al., 2019).

Studies focused on measuring "despair" are limited; only two individual-level studies have been published to date. Gaydosh et al. (2019) measured changes in indicators of despair (i.e., depressive symptoms, suicidal ideation, alcohol, and drug use behaviors) in a longitudinal study from youth to adulthood. They report that suicidal ideation, depressive symptoms, marijuana use, and heavy drinking increased among all racial/ethnic groups and education levels as the cohort aged from adolescence through their late 30s. Using substance use disorder and suicide attempt as proxy indicators of despair, Na et al. (2022) find an association with intergenerational suffering in parenting and childhood experiences and that having at least one psychiatric diagnosis was a strong predictor of individuals reporting both lifetime substance use disorder and suicide attempt.

Currently, only one study has investigated the independent construct of despair. Using longitudinal data following a cohort for 22 years starting at age 9, Copeland et al. (2020) constructed a measure of cognitive despair using variables from psychiatric interviews to test the association between cognitive despair and suicidality and substance use. Their findings suggest that accumulated individual-level experiences of cognitive despair and currently reporting cognitive despair symptoms increases the odds of suicidality and drug use disorders, but not alcohol use disorders. Interestingly, despair scores were highest among Blacks and lowest among AIANs, yet socio-demographic variables did not systematically moderate the relative associations between despair scores and outcomes. More research is needed to reconcile "diseases of despair" (morbidity upstream from mortality) with observed racial/ethnic differences in SIM outcomes.

Some studies have taken a different approach focusing on causes of despair, defining despair as the behaviors it manifests (e.g., suicide and addiction). Presentation of substance abuse, suicidality, and multiple psychiatric diagnoses increasingly reflects real-world clinical experiences Sterling & Platt (2022) argue that rising "despair" and associated morbidities are an expected human response to challenges to the ancestorial human life cycle. Essentially, high rates of SIM-related outcomes are part of the human adaptive response because current U.S. social and economic arrangements create insurmountable challenges and our programmed responses that have led our ancestors to prosperity ineffective.

No studies have established a contextual or community-level equivalent measure to test the deaths of despair framework. Empirically, individual- or household-level measures of socio-economic indicators such as education and income likely serve, in part, as proxy measures for community environmental conditions that influence patterns of SIM mortality. Research finds contextual factors such as demographics and community characteristics are independently associated with SIM mortality outcomes across geographies, but consistent links have not been established between measures of the socio-economic environment and SIM outcomes across groups (Case & Deaton 2015, 2017; Frankenfeld & Leslie, 2019; Monnat, 2018; Shiels et al., 2020; Woolf & Schoomaker, 2019). Despite Case & Deaton's use of deprivation to establish the "deaths of despair" framework, no subsequent studies have applied deprivation measures to study SIM-related outcomes. Some efforts have been made to generate other composite measures, yet those focus overwhelmingly on economic indicators (e.g., Knapp et al., 2019; Monnat, 2018; Rhum, 2018). Thus, the interplay between socio-demographic characteristics, the socio-economic environment, and place-based effects remains largely unknown.

Social Epidemiology of SIM

"Health inequality is the result of social structured inequity, reflecting historically embedded structural differences that produce health divides." (Galea & Keyes 2018 p. i5)

While Case & Deaton's work has renewed attention to the socio-economic context's critical influence on health outcomes, the idea is not new. The "deaths of despair" framework utilizes several aspects of the SDOH, a well-established model used to understand the differential distribution of exposures related to health outcomes at a population level (Solar & Irwin, 2010). The SDOH establishes conceptual pathways linking upstream factors in the socio-economic environment with downstream health behaviors and outcomes, similar to relationships implied in the "deaths of despair" framework (Braveman et al., 2011; Pickett & Wilkinson, 2015; Shanahan et al., 2019; Siddiqi et al., 2019). Recently researchers have underscored the conceptual and empirical links between "deaths of despair," SIM outcomes, and the SDOH (Katz et al., 2020; Siddiqi et al., 2019; Venkataramani & Tsai, 2019; Zeglin et al., 2019). The "deaths of despair" framework notably lacks specificity, allowing adaption, yet making it insufficient to frame the dynamic interactions that are likely influencing SIM risk.

A significant strength of the SDOH Health framework is that it emphasizes how unequal distribution of risk and protective factors are associated with health disparities across population groups (Solar & Irwin, 2010). Thus, this model is well-suited for identifying and addressing factors related to inequities across race and socio-economic gradients. Population health research finds upstream social statuses, such as race, sex, and socio-economic status, significantly influence other health outcomes (Berkman, 2009; Braveman et al., 2011; Pickett & Wilkinson, 2015; Solar & Irwin, 2010; Williams et al., 2019). SIM rates are also patterned across these groups, suggesting that upstream factors may operate differently depending on social group, making it critical to disentangle the differential effects of the social determinants of SIM across groups (Diez-Roux, 2017; Rockett et al., 2016).

Though the established SDOH model stresses the link between socio-economic circumstances and health, research on SIM outcomes rarely incorporates contextual-level factors. This limited focus reflects the historical hegemony of individual-level factors in studies of self-injurious behaviors and associated causes of death (Alcántara & Gone, 2008; Galea & Keyes, 2018; Marsh, 2020; Nock et al., 2019). For more than a century, environmental factors have been implicated as significant risk factors for outcomes such as suicide (beginning with Durkheim), yet they remain neglected in the literature (Berkman, 2009; Durkheim, 1952; Marsh, 2020). As a result, for SIM, and suicide in particular, little is known about contextual factors associated with county-level suicide rates (Steelesmith et al., 2019). Overall, research suggests that contextual factors underly the high and increasing rates of SIM, especially for drug-related deaths in the context of the opioid epidemic, but additional knowledge on the social determinants of SIM is gravely needed to inform prevention efforts (Rockett et al., 2022; Kurani et al., 2020**;** Monnat et al., 2019; Park et al., 2020**;** Steelesmith et al., 2019).

This deficit extends to studies on racial inequities; few current studies incorporate race and contextual-level factors associated with SIM outcomes. Contextualizing environmental risk factors can promote a more comprehensive understanding of racial disparities by incorporating the political economy of health, structural racism, and racially-contextualized inquiry (Diez-Roux, 2012; Gone et al., 2019; Jackman & Shauman, 2020; Wexler et al., 2015; Williams et al., 2019). Socio-economic factors influencing SIM risk are best addressed via upstream intervention and prevention efforts, such as changes in policy and social norms; thus, improving our understanding of the social determinants of SIM is critical to population health promotion (Compton & Shim, 2015). Research from this perspective is necessary to develop prevention efforts designed to shift population-level exposure through upstream methods such as policy while also focusing on those at the highest risk (Fitzpatrick, 2018; Keyes & Galea, 2018).

The relatively new emergence of the “deaths of despair” and SIM perspectives contrasts with previous work that embraces a longstanding psycho-centric focus. Thus, a knowledge gap exists around the shared social determinants of SIM-related deaths. Much more is known about socio-economic factors associated with each cause of death individually, with less available on the differential impact across racial groups. Research on individual causes of death is limited in its usefulness in informing population-level prevention. Contextualizing SIM within the “deaths of despair” and SDOH conceptual frameworks allows for the identification of multiple common upstream socio-economic factors that can be translated into prevention efforts that do not target one specific outcome but can impact many while also avoiding blaming individuals (Felner & Felner, 1989; Galea & Keyes, 2018; Rockett et al., 2016). As an innovative new concept, SIM research is a growing field in which researchers’ calls to investigate the relationship between the socio-economic environment and SIM remain unmet (Rockett et al., 2016). Reviewing results from existing research on the social determinants of suicide, alcohol-, and drug-related deaths can help guide new research to fill gaps in the literature on the socio-economic influences on SIM rates and how these associations may vary across race.

Social Determinants of SIM

Existing studies investigating the social determinants of SIM or composite measures of suicide, alcohol-, and drug-related deaths originate from the "deaths of despair" literature, with little or no published research on SIM specifically. Thus, most knowledge in this area comes from research investigating individual causes of death limited by narrow cause of death classifications. Findings from this body of research indicate that it is difficult to distinguish between suicides and drug-related deaths across multi-level geographical units, suggesting the use of a composite category such as SIM would improve empirical investigations into the social determinants of these deaths (Choi et al., 2019; Katz et al., 2020).

A review of studies on SIM-related causes demonstrates that these deaths share multiple social determinants, all of which should be considered as points for interventions that could potentially be used to prevent numerous causes of premature death. Only one study has investigated how SIM and suicide individually may be associated with contextual social determinants. Rockett et al. (2022) used an analysis assessing trends in the state-level ratio of SIM to Suicide rate, comparing 1999-2000 to 2018-2019 and associated contextual factors. Results indicated the magnitude of SIM rates was associated with contextual factors. SIM and suicide rates did not share any specific social or demographic determinants at the state level, though the significant factors shared categorical overlap (e.g., opioid prescriptions and opioid misuse). The authors cite their methodology as a limitation and highlight this as a critical area for future research.

Overall, shared social determinants of SIM can be grouped into four general areas: contextual circumstances and living conditions (e.g., housing), social resources and opportunities (e.g., education), material resources and opportunities (e.g., employment), and composite measures of social and material deprivation. These constructs and their associated factors are discussed below.

Contextual Circumstances and Community Living Conditions.

Geography. Geographic variation in SIM-related causes suggests that contextual characteristics influence mortality. Independently, suicide, alcohol-, and drug-related mortality rates tend to cluster by geographical areas, where adjacent counties and states are more likely to have similar mortality rates (Singh et al., 2017; Peters et al., 2019; Shiels et al., 2020). Recent findings by Rockett et al. (2021; 2022) show that SIM rates have been increasing across all regions of the U.S. since 1999, and geographic differences in SIM rates are partially attributable to the type of medicolegal death investigation used at the state level. Some research correlates the state- and county-level variation in mortality to local policies. For example, studies of suicide rates find more variation across states than within, potentially attributable to differences in state-level policies, such as firearm legislation that correlate with firearm suicide (Rockett et al., 2022; Kaplan & Mueller-Williams, 2019; Phillips, 2013; Steelesmith et al., 2019). Similar findings show that alcohol control policies impact alcohol-related harms (Giesbrecht et al., 2015; Mathurin & Bataller, 2015; Wagenaar et al., 2010). There is significant variation between and within states for drug-related deaths, especially in those with high mortality rates (Frankenfeld & Leslie, 2019). The geographic patterning of opioid mortality is influenced by the type of opioid that dominates the drug environment. Federal, state, and local governments employ different policy approaches to controlling the opioid epidemic producing mixed effects on prescription opioid- and illicit opioid-related deaths (Cerdá et al., 2021).

Population Density. A consistent focus of SIM-relevant literature is on rural-urban differences in mortality rates. Overall, studies indicate SIM rates tend to be higher in rural areas compared to urban areas, but SIM-related causes do not account for the observed overall rural mortality penalty, which research focused on rural Whites suggests is more attributable to suicides. However, from 1990-2018, SIM mortality rates increased in all areas, with larger increases in metropolitan versus non-metropolitan areas for drug-related deaths and slightly larger increases in suicides and alcohol-related deaths in non-metropolitan areas (Monnat, 2020).

Housing. Loss of housing via eviction or foreclosure is associated with higher SIM rates (Bradford & Bradford, 2020; Fowler et al., 2015; Stone et al., 2018). For drug and alcohol overdose deaths, the positive relationship between eviction and mortality rates is more potent for urban versus rural counties (Bradford & Bradford, 2020). Characteristics of the housing environment are also differentially associated with SIM causes across socio-demographic groups, with white men showing increased vulnerability to SIM during the Great Recession's housing crisis (Kerr et al., 2017). Studies find that foreclosures and decreases in housing prices are associated with higher suicide and opioid-related mortality rates only among whites, with the largest effects on White men (Brown & Wehby, 2019; Houle & Light, 2017). Another study of drug-related suicides and other drug-related deaths found that multiunit housing availability and percent crowded housing were significantly associated with Black mortality rates with no effect on Whites (Frankenfeld & Leslie, 2019).

Healthcare. Barriers to adequate treatment contribute to adverse health outcomes and racial disparities in mental health and addiction-related outcomes (Montiel Ishino et al., 2020; Bowen & Walton, 2015; Martin et al., 2013). Rockett et al. (2022) find that percent of state populations without health insurance is positively associated with increasing SIM rates. One study using data from counties in Florida found that larger numbers of mental health professionals and percent uninsured were associated with higher SIM rates, while counties with higher portions of the population reporting a recent medical checkup had lower rates (Zeglin et al., 2020). Similar findings on the percent uninsured population are reported for suicide but are sometimes contrary for drug-related mortality due to the relationship between prescription opioids and medication-assisted opioid use disorder treatment (Cerdá et al., 2021 Connery 2015; Krawczyk et al., 2020; Frankenfeld & Leslie 2019; Larochelle et al., 2018; Steelesmith et al., 2019).

Community/neighborhood Characteristics. Other contextual characteristics of the living environment are also studied. For example, lower SIM rates are lower for men in states with better state-level mental health ratings (Katz et al., 2020). At a lower level of analysis, studies investigating relationships between neighborhood characteristics and SIM-related causes find that some objective and subjective measures may impact SIM risk. Among Veteran Health Administration users, one study found neighborhood racial residential segregation contributed to racial disparities in all-cause mortality among AIANs and Blacks, but not Whites (Wong et al., 2020). For SIM-related causes, research suggests higher percent White population is associated with higher suicide rates and drug-related deaths, while racial/ethnic diversity is associated with lower incidence rates for drug-related suicides and drug-related deaths for Blacks, but not Whites (Congdon, 2011; Frankenfeld & Leslie 2019; Sengupta & Jantzen, 2019; Zoorob & Salemi, 2017).

The quality of neighborhood characteristics may also play a role. Walkable neighborhoods with leisure opportunities are associated with a decreased prevalence of depression and substance abuse (Renalds et al., 2010). Higher risk for alcohol-related harms is associated with lower neighborhood socio-economic status and higher alcohol outlet density (Cerdá et al., 2010; Giesbrecht et al., 2015; Mulia et al., 2018). An analysis of data from two southern states also finds that alcohol outlet density is higher in predominately Black neighborhoods. This demonstrates how potential SIM risk could be differentially distributed by structural racism mechanisms (Scott et al., 2020). Findings from some of my previous research on AIAN suicide suggest the socio-demographic profile of AIAN suicide, alcohol-, and opioid-related suicide decedents differ from each other and across counties with $<$ or $\geq$ 20% AIAN population (Mueller-Williams, 2021). For example, there were increased relative odds of opioid-related suicide and decreased relative odds of alcohol-related suicide among AIAN female suicide decedents with lower levels of risk factors.

Social resources and opportunities.

Exposure to Structural Racism. Racial health inequities result from longstanding structural inequalities that harm marginalized groups' health and well-being through numerous pathways (Williams et al., 2019). Including SIM, upstream determinants of premature mortality among AIANs and Blacks are linked to experiences with structural violence and racism, such as colonialism, Historical Trauma, Racial Trauma, and Slavery (Hartmann et al., 2019; Shahram, 2016; Williams et al., 2019). Measurement difficulty significantly limits studies connecting racism-related contextual exposures to SIM but improving our understanding of how structural racism impacts health is critical to addressing health disparities (Bailey et al., 2017; Farahmand et al., 2020). Overall, perceived and objective experiences with racial discrimination increase the risk of suicidality, substance use, and adverse mental health outcomes in racial/ethnic minorities (Bailey et al., 2017; Oh, et al., 2019; Paradies et al., 2015; Wang et al., 2020). Among AIANs, exposure to experiences related to colonialism (e.g., having personal or family exposure to boarding schools) is associated with increased risk for SIM-related outcomes; exposure to traditional lifeways, connection to cultural practices, and cultural continuity are generally protective (Chandler & Lalonde, 2008; Shahram, 2016). Evidence from some studies suggests that structural racism-related factors may significantly influence Black drug-related mortality and may play a more important role than socio-economic indicators at the county level (Frankenfeld & Leslie, 2019). Experiences with racial discrimination are associated with increased risk for substance abuse, mood disorders, and suicidality, among Blacks with some studies finding that the effect may be enhanced for Blacks of higher socio-economic status (Carliner et al., 2016; Clark et al., 2015; Oh et al., 2020).

Education. Evidence on the relationship between education and SIM generally suggests that lower educational attainment is associated with an increased risk for SIM-related death (Fishman & Gutin, 2021; Frankenfeld & Leslie, 2019; Zeglin et al., 2020). Importantly, education is linked to other protective resources, including income, employment, and social capital-related factors that may protect against SIM risk in a dynamic causal pathway (Fishman & Gutin, 2021; Case & Deaton, 2015, 2017; Gutin & Hummer, 2020; Li et al., 2011; Meara et al., 2008; Monnat, 2019; Montez et al., 2019; Siddiqi et al., 2019; Sasson & Hayward, 2019). The benefits conferred by education then manifest in factors more proximally related to SIM outcomes. Fishman & Gutin (2021) found that among adults ages 33-44 years, lower education levels are associated with SIM-related behaviors—suicidal ideation, drug use, and frequent binge drinking—but for those with less than a college degree, 20% of the relationship between education and suicidal ideation and drug use was explained by financial losses.

The unequal distribution of opportunity and education-related resources is further demonstrated by the association between education and SIM across racial groups. Research finds that education inequality in health outcomes is increasing and higher for Blacks and women, yet research focusing on the relationship between educational attainment and SIM emphasizes the mortality penalty observed in lower-educated Whites (Case & Deaton, 2015, 2017). Evidence suggests SIM contributes to increasing educational differences in premature mortality, but the effect is magnitudes stronger for Whites than Blacks (Geronimus et al., 2019). Case & Deaton highlight racial differences in education relative to income, finding that SIM rates are increasing among lower-educated Whites to the extent that by 2015, low-educated White mortality rates were higher than those for Blacks overall (Case & Deaton, 2015, 2017). These trends may reflect diminished returns on education for Blacks relative to Whites; the protective effects of educational attainment on suicidality are attenuated for Blacks relative to Whites (Assari et al., 2018; Montez et al., 2012). There is little evidence regarding the effect of education on SIM among AIANs. Existing work reports mixed results on the relationship between individual and parental educational attainment and SIM-related outcomes (Akins et al., 2013; Bolton et al., 2014; HeavyRunner-Rioux, 2010; O'Connell et al., 2007; Wexler et al., 2015; Whitbeck et al., 2001). Studying education effects in this population is complicated by the educational profile of AIANs, which experience the highest high school dropout rates and lowest percentage with a 4-year college degree across racial groups (National Center for Education Statistics, 2019; Ogunwole et al., 2012).

Social Capital-related Factors. The SDOH model implicates social capital as a critical social determinant of population health (Solar & Irwin, 2010). Though measured differently across studies, higher levels of social capital-related factors are generally associated with lower SIM rates, though the effect may be different across socio-demographic groups and specific measures used (Heyman et al., 2019; Katz et al., 2020; Smith & Kawachi, 2014; Villalonga-Olives et al., 2020; Zoorob & Salemi, 2017). Some of the essential elements of social capital implicated in SIM research include family relationships. Higher rates of drug suicides and drug-related deaths are found in counties with an elevated prevalence of family distress (Monnat, 2018). Being divorced or unmarried is associated with increased suicide risk, but the relationship is moderated by sex, age, and geography (Rockett et al., 2022; Kposowa et al., 2020; Kyung-Sook et al., 2018; Yip et al., 2015). Other important factors associated with lower SIM rates include social capital-granting institutions (e.g., religious establishments) and social integration (Chen et al., 2020; Monnat, 2018; Steelesmith et al., 2019). Some research reports that social capital can be associated with increased risk for substance abuse, potentially through a contagion mechanism (Child et al., 2017; Kuntsche et al., 2017; Villalonga-Olives & Kawachi, 2017).

Material resources and opportunities.

Economic Disadvantage. A large body of research investigates the links between aspects of the economic environment and SIM-related causes. Though most studies generally report that economic disadvantage or insecurity is associated with increased risk for SIM-related outcomes, there is considerable effect modification across socio-demographic subgroups and over time. For drug-related deaths, research suggests mortality rates are influenced by "supply-side" factors influencing the drug environment and "demand-side" factors influencing individual drug use, such as socio-economic conditions (Dasgupta et al., 2018; Kiang et al., 2020; Rhum 2018).

Generally, macroeconomic decline and its downstream effects are associated with increased SIM risk, though the mechanisms are not well established (Catalano et al., 2011). The suggested mechanism of influence is through decreased economic opportunities such as unemployment, low socio-economic status, disability, and increases in concentrated poverty (Altekruse et al., 2020; Cerdá et al., 2021; Katikireddi et al., 2017). This pathway is supported by findings that SIM rates concentrate in economically disadvantaged areas (Collins et al., 2018; Heyman et al., 2019; Katikireddi et al., 2017; Monnat, 2018).

Research suggests that fluctuations in economic conditions are more powerful influencers of SIM than absolute measures of socio-economic status. Higher SIM rates are found in counties with long-term medium, increasing and decreasing economic insecurity, though mortality rates increased at a similar pace for all counties from 2000-2015 (Heyman et al., 2019; Knapp et al., 2019). Individual-level findings are similar; accumulated indicators of financial strain and limited economic mobility relative to previous generations are positively correlated with suicide attempts and drug-related deaths (Elbogen et al., 2020; Heyman et al., 2019).

The association between economic conditions and drug-related deaths depends on the type of opioid that dominates the local drug environment and population density (Linton et al., 2017; Monnat, 2018; Pear et al., 2019). Relevant studies on drug use and suicide find that for some economic indicators, such as unemployment, associations vary significantly by race, sex, and community characteristics (Frankenfield & Leslie, 2019; Kaufman et al., 2020; Rudolph et al., 2020). One study found that poor Blacks reported being more optimistic and having better mental health than their White counterparts, especially when facing economic disadvantages (Dobson, Graham, & Dodd, 2021). Recent and rapid changes in the relative distribution of intentional and unintentional opioid-related deaths across racial groups suggest that the nature of economic pathways increasing for opioid overdose are changing; thus, future research should prioritize this area (Cerdá et al., 2021).

Income and Poverty. Lower-income and higher poverty rates are generally associated with increased risk for SIM-related outcomes (Phillips, 2013; Zeglin et al., 2020). Associations between SIM and poverty are relatively consistent. Elevated area poverty measures are positively associated with opioid-related deaths, alcohol-related harms, suicide, and alcohol-related suicides (Frankenfeld & Leslie, 2019; Kerr et al., 2017; Pear et al., 2019; Rhew et al., 2020). There is a less consistent relationship with income, potentially related to a failure to account for the impact of income inequality or relative income (Bor et al., 2017; Bosworth, 2018; Case & Deaton, 2017; Diez-Roux, 2017; Gutin & Hummer, 2020; Meara, et al., 2008; Pickett & Wilkinson, 2015; Phillips, 2013; Rhum, 2018; Shanahan, 2019; Sutchfield & Keck 2017; Venkataramani & Tsai, 2020; Fishman & Gutin, 2021). For drug-related deaths, income inequality, specifically the lack of resources allocated to the bottom 20% of earners, is associated with higher rates. (Thombs et al., 2020). Case & Deaton argue that income nor income inequality are primary drivers of SIM rates among Whites (2017). They find a strong correlation between SIM and real median household income, but trends in median income do not match those for mortality when stratified by education level. An analysis of the general population finds weak and non-significant correlations between SIM and county-level median income, income inequality, and percent living in poverty at the county level (Siddiqi et al., 2019). Other analyses suggest the association may vary by population density, geography, and socio-demographic subgroup (Frankenfeld & Leslie, 2019). One study reported higher median income across Florida counties was associated with significantly higher SIM rates and that rates increased as median age increased in lower median income counties (Zeglin et al., 2020).

Employment. The effect of employment status on SIM may be indirect (i.e., dependent upon the material resources it confers), yet unemployment and disengagement from the labor market are key factors included in SIM-related literature (Milner et al., 2014). Evidence indicates that unemployment, job insecurity, and labor market non-participation increase risk for SIM and SIM-related conditions, such as mental illness and substance abuse (Catalano et al., 2011; Case & Deaton, 2015; Dasgupta et al., 2018; Gutin & Hummer, 2020; Hawkins et al., 2020; Milner et al., 2014; Pear et al., 2019; Prins et al., 2018; Rudolph et al. 2020; Sangupta & Jantzen, 2019; Steege et al., 2018; Rockett et al., 2022). In a longitudinal study of the impact of automotive plant closures on SIM death rates, Default et al. (2022) finds an association between job loss and SIM; the authors suggest collective feelings of employment being threatened due to macroeconomically caused job losses in the automotive sector leads to an increased risk of SIM death. The association between unemployment and SIM causes also varies across geographical areas and socio-demographic subgroups (Frankenfeld & Leslie, 2019; Rudolph et al., 2020; Trgovac et al., 2015). The relationship between unemployment and SIM remains unclear and likely involves other contributing factors. For example, long-term suicide rates have increased relatively linearly despite cycling unemployment (Harper et al., 2020).

Occupation Type and Quality. Among employed individuals, the quality of work may also influence SIM risk. Studies suggest SIM-related outcomes tend to be higher in occupations with specific characteristics such as low autonomy and high-effort, including blue-collar, manual labor, and service industry work (Gutin & Hummer, 2020; Hawkins et al., 2020; Prins et al., 2018). Occupations with the highest prestige (e.g., managerial positions) are generally associated with decreased risk, except for healthcare workers, for which research suggests there is an increased risk, especially for drug-related outcomes, including death (Gutin & Hummer, 2020; Hawkins et al., 2020; Prins et al., 2018; Chen et al., 2020). Research has focused on manufacturing jobs, especially as this sector relies heavily upon macroeconomic trends and policies. For example, trade liberalization and the inability of unions to protect workers from mass layoffs in manufacturing are associated with an increased risk of SIM death (Default et al., 2022; Pierce & Shott, 2020; Venkartarmani & Tsai, 2020). At the state level, the percent population employed in manufacturing is negatively associated with growing SIM rates (Rockett et al., 2022). Local shocks to manufacturing jobs are also generally associated with SIM deaths, especially among younger males who comprise most individuals employed in this sector (Autor et al., 2019; Pierce & Shott, 2020; Venkartarmani & Tsai, 2020; Monnat, 2019; Default et al., 2022).

Economic Recession. Some research uses the Great Recession to investigate the impact of economic recession on SIM. Research finds that suicide and alcohol-related suicide rates tend to increase during recessionary periods or decrease when economic activity is high and differs across race/ethnicity and sex (Nandi, et al. 2012; Kerr et al., 2017; Phillips & Nugent, 2014; Granados & Diez Roux 2009; Granados 2005;). Tilstra et al. (2021) find SIM-related death increases track with the timing of the Great Recession among Whites and Blacks however, some suggest that the Recession did not meaningfully interrupt existing trajectories of suicide mortality (Strumpf et al., 2017). Similar findings are reported increased prescription opioid mortality and substance use disorders (Carpenter et al., 2017; Strumpf et al., 2017). Associations between economic recession and alcohol are mixed, potentially due to the cause-effect time lag associated with alcohol-related causes such as cirrhosis (Catalano et al., 2011; Tapia Granados & Diez Roux, 2009).

***Macroeconomic Factors*.** Macroeconomic policy exposures and types of economic sectors that dominate local labor markets are also implicated in SIM risk. Exogenous shocks related to policy suggest that changes in trade-related policies that create job losses, decrease demand for manufacturing labor, and expose regions to higher import competition increase SIM-related deaths, especially among people with lower education, men, and in areas with dominant manufacturing economies (Autor et al., 2019; Dean & Kimmel, 2019; Pierce & Schott, 2020; Venkataramani et al., 2020). Studies on policies that increase after-tax income (e.g., earned income tax credit, minimum wage) find that they decrease suicide rates among lower-educated adults, with some finding effect modification across socio-demographic subgroups (Dow et al., 2020; Kaufman et al., 2020; Gertner et al., 2019). The type of industry that dominates local labor markets is also associated with county-level SIM rates; research finds drug-related mortality rates are higher in counties reliant upon mining and lower in counties dominated by public sector employment and farming (Monnat, 2018). Similarly, two studies have found that SIM rates increased in sample manufacturing counties after automotive plant closures (Venkataramani et al., 2020; Default et al., 2022).

The macroeconomic shock of COVID-19, especially on employment, is unusually severe, yet research finds that high SIM rate counties did not experience heightened vulnerability to COVID deaths (Dobson, Graham, & Dodd, 2021). However, another study found that the early pandemic and associated economic recession were associated with a 10-60% increase in deaths of despair, compared to pre-pandemic levels and that these increases were primarily concentrated in men under the age of 55 years (2020). It will be important for future research to study the impact of the COVID-19 pandemic on SIM rates as new data become available (Dobson, Graham, & Dodd, 2021; Mulligan 2020).

Social and Material Deprivation.

Because SIM causes share multiple social determinants, composite social and material deprivation measures provide a more comprehensive approach to investigating their social determinants. Measures are operationalized differently across studies, but those using area-based deprivation measures generally find higher rates of SIM-related outcomes in high deprivation areas. Suicide attempts and deaths are independently associated with higher deprivation levels, even after adjustment for individual-level characteristics (Steelesmith et al., 2019; Yildiz et al., 2019). From 1999-2016, the highest baseline suicide rates occurred in rural areas; however, rates increased faster in places with lower deprivation across all population densities (Steelesmith et al., 2019). Similarly, drug- and opioid-related deaths are higher in more deprived areas, with rates increasing at all deprivation levels (Chichester et al., 2020; Kurani et al., 2020). Studies find a dose-response relationship between alcohol use and deprivation level, higher levels of deprivation exacerbate risk for alcohol-related harms (Bellis et al., 2016; Hawton et al., 2001; Katikireddi et al., 2017; Matheson et al., 2012).

Measures of multidimensional social and material deprivation are commonly used internationally, often in place of simplistic measures of poverty (Glassman, 2022). However, the use of these measures in the U.S. is extremely rare. However, the U.S. Census has a newly developed area-based multidimensional deprivation measure that holds promise for investigating the effect of social and material deprivation on SIM-related outcomes.

Social Determinants of SIM: Areas to Prioritize for Research

> *"Future research on SIM trends will need to evaluate a wide array of potential individual-level and contextual determinants (eg, social, economic, political, health, and environmental), disaggregating SIM by such variables as race/ethnicity, military veteran status, state, and region."* (Rockett et al., 2016, p.1078)

The substantial overlapping social determinants of suicide, alcohol, and drug-related deaths highlight three significant areas to prioritize for future research: 1) robust mortality outcome measures, such as SIM, 2) multidimensional measures that incorporate several socio-economic determinants, and 3) understanding the relationship between social determinants of SIM across racial groups. Studies using composite and individual mortality measures tend to use single proxies as indicators for the social and economic environment. For example, in Durkheimian studies of suicide, social integration is usually measured using variables on divorce and religiosity; social regulation is proxied by economic conditions, such as unemployment rates (Phillips, 2013). However, the social determinants of SIM are part of a dynamic system, so individual correlates alone are proxies for the socio-economic environment but do not give much information or a holistic understanding of the contextual factors driving SIM and differences across groups.

As presented by Case & Deaton (2017), social and material deprivation measures hold promise in addressing this gap. Applying deprivation measures to SIM may clarify associations between economic factors and premature mortality. Despite this, area-based multidimensional deprivation measures remain underutilized even in the "deaths of despair" literature. Interestingly, much of this literature is editorial, serving as a platform for criticism and calls for empirical research. Conceptual and empirical details surrounding the "deaths of despair" framework are under debate and have garnered significant criticism (Boyd, 2020; Diez-Roux, 2017; Guo, 2017; Masters et al., 2018; Mehta et al., 2016; Muennig et al., 2018; Plunk et al., 2018; Schmid, 2016; Scutchfield & Keck, 2017; Shanahan et al., 2019).

Particularly salient critiques of Case & Deaton's work underscore the problems that arise with an explicit focus on White demographic subgroups. Findings from the original "deaths despair" research constructed a narrative describing the plight of disenfranchised working-class White men in midlife, despite evident disparities in mortality rates across racial groups. The idea that an epidemic of despair was ravaging White American lives garnered extensive scientific, political, and media following (Guo, 2017; Joint Economic Committee, 2019; Zarroli, 2020). As a result, most of the scientific work relevant to "deaths of despair" has focused on Whites, minimizing evidence suggesting this is "not just a White problem" (Blacksher, 2018; Cherlin, 2018; Masters et al., 2018; Meit et al., 2019; Muennig et al., 2018; Scutchfield, 2019; Shiels et al., 2017; Siddiqi et al., 2019; Squires & Blumenthal, 2016). More research is needed to understand how these causes of death and related factors operate across racial groups, sex, and socio-economic status (NAS, 2021).

Some studies using composite mortality measures emphasize the burden of SIM on Whites by describing a racial health disparities paradox, where Black Americans are not disproportionately burdened by suicide, alcohol-, and drug-related mortality compared to their White counterparts, with few studies reflecting upon high rates among AIANs (Case & Deaton 2015, 2017; Kochanek et al., 2019; Shiels et al., 2020; Woolf & Schoomaker, 2019). However, this approach can be problematic. Not accounting for racial differences in SIM mortality and focusing "deaths of despair" research on Whites distracts attention and resources away from enduring racial inequities and underlying causes (e.g., social class) that impact health across groups (Boyd, 2020; Diez-Roux, 2017; Guo, 2017; Muennig et al., 2018; Plunk et al., 2018; Scutchfield & Keck, 2017).

As a whole, the "deaths of despair" literature presents a narrative that seems to express inherent institutional bias. For example, the sharp focus on Whites may have brought "deaths of despair" into the American consciousness. However, suicide, alcohol-, and drug-related deaths have been endemic in AIAN communities for decades, and arguably "despair" has been a prominent factor influencing the well-being of oppressed groups such as AIANs and Blacks for centuries as a product of colonialism and slavery (Davis, 2019; Hartmann, et al., 2019; Komro, 2018; Shiels et al., 2017, Wexler et al., 2015; Williams et al., 2019). The contrasting SIM rates between AIANs and Blacks, despite relatively similar experiences with structural oppression compared to Whites (or "disadvantaged" Whites), is a significant gap in knowledge that literature has not addressed. Few studies on SIM or the "deaths of despair" framework meaningfully incorporate diverse racial/ethnic groups; even fewer include AIANs, who are the group most heavily impacted by these causes of death (Copeland et al., 2020; Shiels et al., 2020; Woolf et al., 2018; Woolf & Schoomaker, 2019). These staggering epidemiological inequities in SIM experienced by AIANs demands attention from researchers and policymakers (Komro, 2018). Incorporating a critical understanding of racial health disparities into research on premature mortality could provide valuable insights into why experiences of disadvantage or despair produce different responses across populations.

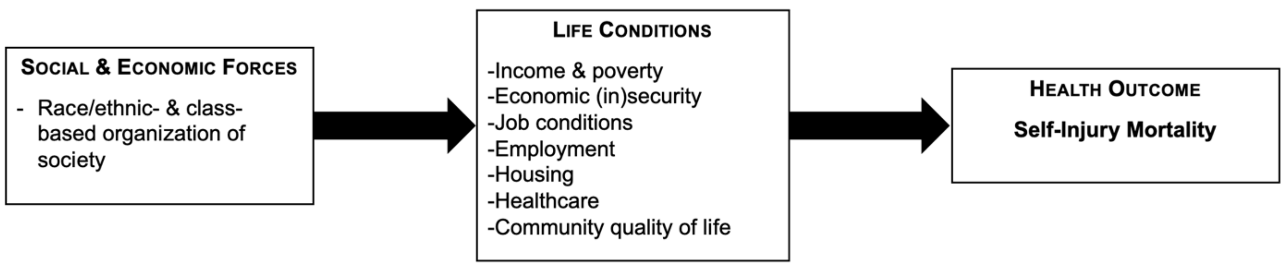
Approach to Study Design and Analysis

Empirical investigations linking socio-economic conditions to differential outcomes in suicide, and alcohol- and drug-related deaths across race are desperately needed to advance our understanding of the social determinants of SIM. A consensus study from the National Academies of Sciences calls for an urgent response to address these causes of premature mortality, emphasizing policy and strategies that address both immediate and upstream causes (2021).

As a burgeoning concept, research using SIM holds promise to inform upstream prevention efforts that target multiple self-harm-related causes of death. Still, very little is known about how suspected social determinants are associated with SIM rates across race groups. SIM is an innovative concept allowing for actionable research findings. Area-based multidimensional deprivation is a good proxy measure for multiple factors implied as social determinants of SIM-related outcomes. However, extant research primarily utilizes independent variables limited to unidimensional economic measures.

To help address gaps in existing research, this study focuses on three domains: 1) SIM, 2) racial inequities, and 3) multidimensional deprivation. While the most appropriate operationalization of the SIM includes suicides, unintentional drug overdose deaths, and deaths of undetermined intent, in this study the SIM measure includes only suicides and deaths of undetermined intent. This study's primary objective is to use the “deaths of despair” and social determinants of health framework to guide an investigation of the relationships between SIM and multidimensional socio-economic deprivation. Because SIM rates (including substance-involved SIM) and MDI rates vary across race, it can be reasonably expected that the effect of MDI on SIM rates may operate differently across racial groups. Figure 5 depicts the combination of the social determinants of health and “deaths of despair” framework postulating conceptual linkages between social determinants and SIM death.

Figure 5. Conceptual Framework for the Social Determinants of Self-Injury Mortality.



To explore this relationship, a sample of individuals who died due to select SIM-related causes of death were extracted from the National Violent Death Reporting System Restricted Access Data (NVDRS). This sample used to construct the dependent variable of SIM rate and substance-involved SIM rates from years 2015 through 2020 for 24 states. The primary independent variables of interest were elements of “life conditions” depicted in Figure 5. All these factors are measured within the U.S. Census Bureau’s Multidimensional Deprivation Index (MDI), thus the MDI data were used as the primary dependent variable for the same years and states as the NVDRS. The NVDRS and MDI datasets were merged at the state-year level, thus producing state-year SIM rates and state-year MDI levels (the unit of analysis is the state-year).

Specific Aims

Conceptually, the approach to this study was completed in three stages. Because SIM and MDI are innovative and new measures, this study included descriptive (step one, aims one and two), single-level (step two, aim three), and multi-level (stage three, aim four) approaches. Stage one objectives involved describing the characteristics of SIM decedents, especially by race, and estimating SIM rates. Stage two included estimating models of the relationship between SIM rate and MDI. And finally, stage three used the geographical nature of the data (i.e., observations nested within states) to allow for potentially differing effects of MDI on SIM rate by state. The following section describes the specific aims of this study and their associated sub-aims.

Step 1: Descriptive.

Aim 1. For MDI values, for each state, for each year 2015-2020, use the continuous measure of state-year MDI to create ordinal groupings and generate categorical variables of MDI. Use MDI quartiles where possible to describe the sociodemographic profiles of SIM decedents.

1a**.** Develop sociodemographic profiles of all SIM decedents within the lowest and highest categorical groupings of MDI.

1b**.** Describe sociodemographic profiles of SIM decedents within the lowest and highest categorical groupings of MDI within each race.

Aim 2. For each state for each year 2015-2020, estimate age-standardized SIM rates.

2a**.** Estimate age-standardized SIM rates for all SIM decedents, and for each race group for each race group (as possible based on sample size restrictions).

2b**.** Compare temporal trends in age-standardized SIM rates for all SIM decedents, and each race group (as possible based on sample size restrictions).

2c**.** Calculate age-standardized SIM rates within the lowest and highest categorical groupings of SIM, and for each race group (as possible based on sample size restrictions).

Step 2: Sing-level modeling.

Aim 3. Use state-year observations (2015-2020) to estimate the direction and strength of the relationship between SIM rate and MDI.

3a**.** Assess the relationship between SIM rate and MDI and potential variation by race.

***3b*.** Examine the relationship between substance-involved SIM and MDI and potential variation by race.

Step 3: Multi-level Modeling.

Aim 3. Use state-year observations (2015-2020) to estimate multi-level models to examine the effect of MDI on SIM and if that effect varies by state.

***3a*.** Specify effect of MDI on SIM across states.

***3b*.** Determine if the effect of MDI on SIM differs by state.

CHAPTER 3: METHODS

This chapter describes the methods of using individual-level and state-level data to explore the sociodemographic characteristics of SIM decedents and the relationship between SIM rate and MDI overall, and across race groups. The goal of this these analyses is to improve our understanding of the relationship between state-level MDI and state-level SIM risk, and how this relationship may vary across race. This chapter begins by detailing the data sources used to construct the independent and dependent variables. It then describes the sample characteristics of each variable, and the statistical procedures employed in analyses.

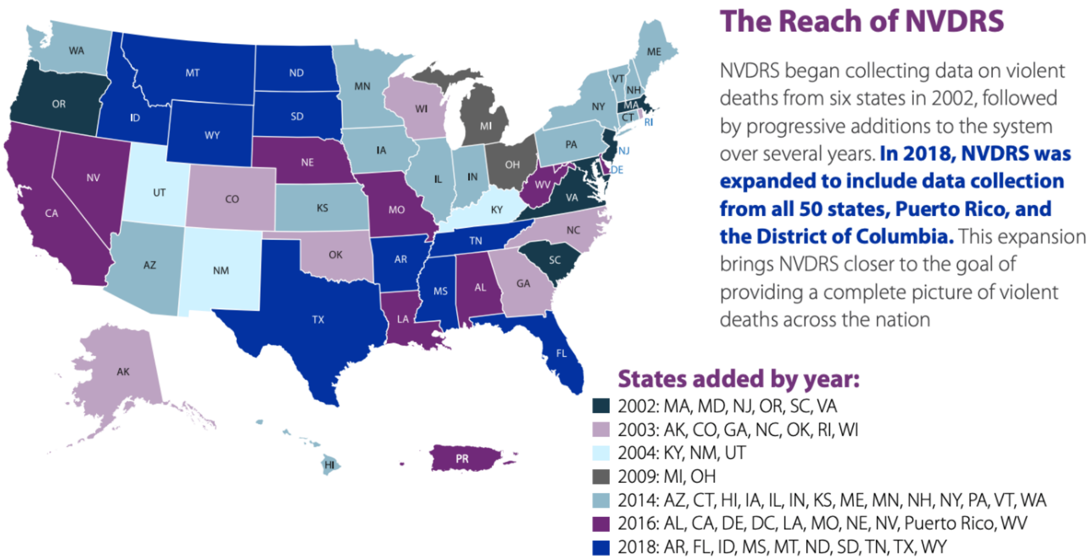
Data Sources

This study used individual-level data on SIM decedents from the NVDRS (used to construct the dependent variable) and data on state-level socio-economic environments (independent variable) from the MDI. These two sources were merged by state and year into a single dataset used for analysis. Details on the nature and use of these datasets is detailed below.

Introduction to the National Violent Death Reporting System

The NVDRS is a unique, state-based surveillance system that records detailed information on all violent deaths, including suicides and deaths of undetermined intent. In this sense, it is an annual census of violent deaths in each state. Seven states participated when the system began in 2003, with several states added each subsequent year. The most recently available data were collected through 2020 and include information on suicides and undetermined intent deaths from 50 states, D.C., and Puerto Rico (figure 6).

Figure 6. Geographic Coverage of NVDRS Data by Year.



Source: CDC, 2020c

The restricted access data include information on individual decedents' characteristics far beyond what is included on death certificates (Kaplan et al., 2017). For example, the NVDRS collects information on location of death, opioid toxicology, blood alcohol level, and provides narratives of the circumstances that precipitated each death. In this study, the NVDRS is used to source the dependent variable, which is based on deaths due to suicide or undetermined intent (details on the dependent variable are described later).

In the NVDRS, information about each decedent is collected at the state-level through death investigations that use linked records from death certificates, coroner/medical examiner reports, and law enforcement reports. Because NVDRS data are generated from death investigations that are more rigorous than standard procedures, there is a decreased risk of misreporting compared to standard death certificates on decedent characteristics. In addition to coded information in variables, there are narratives of the death investigation for each decedent written by each coroner/medical examiner and law enforcement involved with the case. These written accounts can provide important contextualization surrounding recorded deaths.

Key limitations of the NVDRS

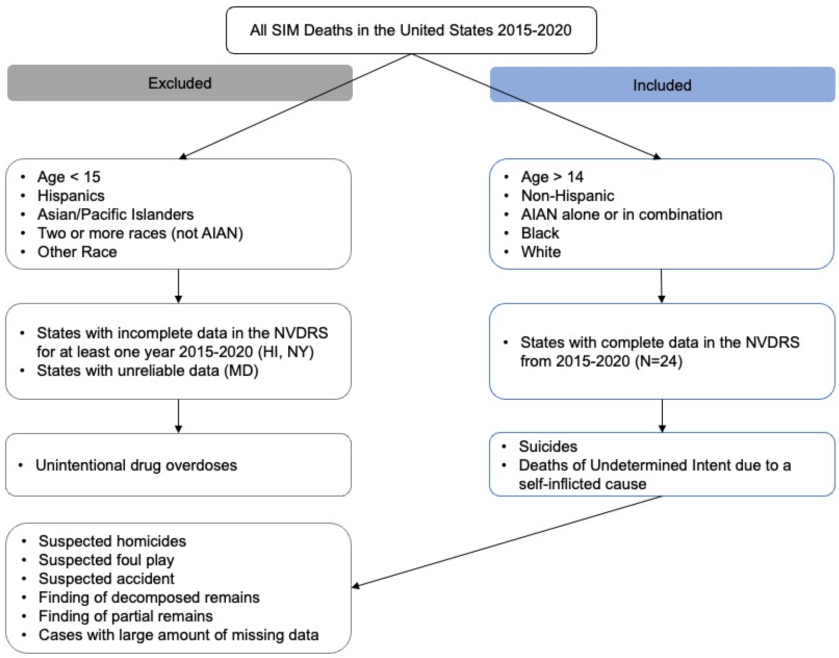
The most significant limitations of NVDRS data originate from the voluntary participation of states over time. Not all states contributed data over the period for which data were collected. Figure 4 depicts the state expansion of the NVDRS (CDC, 2020c). States may also record deaths that actually occurred in other states. This is rare for most states and most years; however, it can cause data irregularities in certain cases (e.g., the states surrounding the District of Columbia).

At an individual level, characteristics associated with the death investigation are optionally recorded by coroner/medical examiners; therefore, there are gaps in data. For example, not all decedents in the NVDRS are tested for alcohol or drugs. However, not being tested for substances does not exclude the death from being drug or alcohol related (e.g., a drug overdose death where the decedent was not tested for drugs or toxicology was not reported). However, information on substance-related deaths and decedent characteristics (e.g., race) is sometimes available through other variables, including the coroner/medical examiner and law enforcement narratives and cause of death information abstracted from death certificates. For example, there are ways the NVDRS data can be used to identify substance-related deaths beyond what is available in toxicology data.

NVDRS Dependent Variable Construction

The primary outcome of interest is state-year SIM rate, with SIM being defined as suicides and select deaths of undetermined intent. Secondary outcomes include the decomposition of SIM causes of death by substance involvement (i.e., alcohol, drugs, or alcohol and drugs). Specific characteristics were used to select the sample of SIM decedents from the NVDRS that was used for analysis. The process of constructing the sample of SIM decedents is described in figure 7.

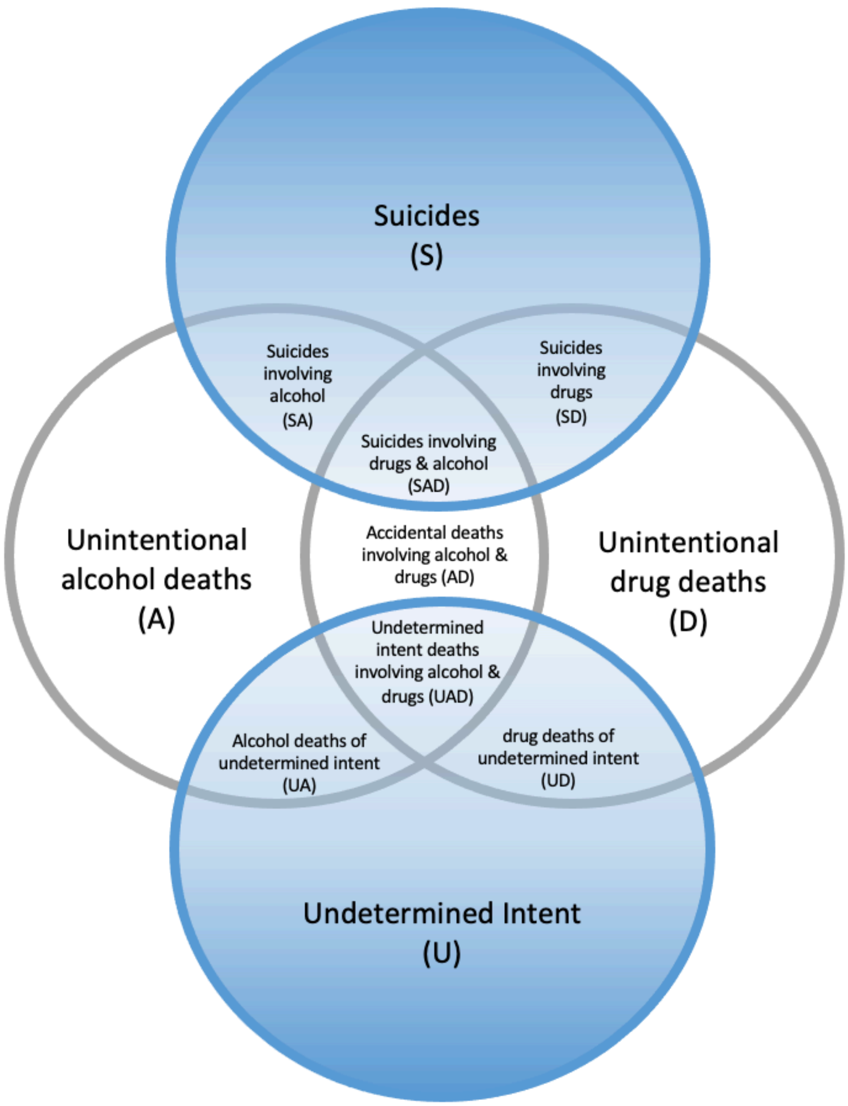
Figure 7. Inclusion Criteria Process for the Construction of the SIM Decedent Sample.



Analyses included only data years 2015 through 2020, only states with complete data for those years, decedents aged 15 years and older, non-Hispanics, and decedents defined as either AIAN alone or in combination with another race, Black alone, or White alone. Two states did not have complete data for the six-year study period (Hawaii and New York) and thus were excluded. One state with complete data (Maryland) was excluded due to data irregularities stemming from a large portion of reported deaths occurred outside of the state (e.g., deaths that occurred in Washington DC but were recorded in Maryland). Thus, accurate rates for Maryland could not be estimated because it was difficult to identify the appropriate denominator. The final sample included 24 states with observations for six years. Only individuals who died by suicide or self-inflicted causes of undetermined intent were included.

Types of SIM causes of death included in the NVDRS are suicides and undetermined intent deaths, with information on if each of those involved alcohol or drugs. Figure 8 depicts the theoretical SIM measure presented in Chapter 3. The areas highlighted in blue indicate the SIM decedent sample that is used in this study, sourced from the NVDRS. Notably, the applied definition of SIM deaths included in this study (i.e., suicides and deaths of undetermined intent) differs from the conceptual definition (i.e., suicides, unintentional drug overdoses, and deaths of undetermined intent).

Figure 8. SIM Causes of Death Included in the NVDRS (Highlighted in Blue).



This study excludes unintentional drug overdose deaths due to data limitations. NVDRS data are of a significantly higher quality than other data sources but do not include information on unintentional drug overdoses, those data come from publicly available death certificates. Data quality is of great importance when assessing substance involvement in deaths and when analyzing data with AIAN populations. Basic information on substance involvement from death certificates is limited and they have a very high rate of racial misclassification among AIANs (Arias et al., 2016; Arias et al., 2021). The more rigorous death investigations associated with deaths recorded in the NVDRS provides more comprehensive and reliable information on people who died by violent means.

Suicides recorded in the NVDRS are straightforward, death investigations and final cause of death was due to intentional self-harm (ICD-10 codes X60-X84). These deaths are defined as resulting from “purposely self-inflicted poisoning or injury” (World Health Organization, 2016). As previously discussed, this requires some reasonable degree of evidence that the death was self-inflicted and intentional. If the coroner/medical examiner determines that sufficient evidence for intentionality is lacking, the death can be classified as an accident or of undetermined intent.

Because deaths classified as undetermined intent (ICD-10 codes Y10-Y34) are inherently defined based on lacking information, the resulting cases are often vague or heterogeneous. Thus, types of deaths classified as undetermined intent can include causes irrelevant to this study (i.e., do not likely reflect self-inflicted injury or cases with extremely limited information). To determine which undetermined intent deaths were relevant, the NVDRS data were evaluated based on a specific definition of undetermined intent used in this study.

Defining Deaths of Undetermined Intent

According to the CDC, deaths included in the NVDRS are based on the World Health Organization definition of violent deaths, “a death resulting from the intentional use of physical force or power against oneself, another person, or against a group or community.” (WHO). This includes traditional suicides and deaths of undetermined intent. The CDC states the rationale for including undetermined intent deaths in the NVDRS:

> Deaths of undetermined intent are included because this category includes deaths with some evidence of intent, but without enough to definitively classify the death as purposeful. Unintentional firearm injury deaths are included because the category is

> likely to include some deaths that are intentional or of undetermined intent. (NVDRS Coding Manual Version 6.0).

Undetermined intent deaths that are conceptually relevant to this study reflect intentional self-harming behaviors. However, some deaths of undetermined intent that appear in the NVDRS include those that should be excluded, such as deaths with active homicide investigations or findings of decomposed or partial remains.

To identify SIM-related deaths that are misclassified suicides or that reflect self-harm behaviors, previous work has used a formula of sampling a 90% of drug-related deaths of undetermined intent (Rockett et al., 2021; Rockett et al., 2022). However, this research used death certificate information only. The NVDRS contains a large amount of additional data, including narratives, that can be used to further identify undetermined intent deaths that merit inclusion in this study.

Deaths of undetermined intent were included in the sample if they met inclusion criteria suggesting the death was due to self-inflicted behavior. This was determined by evaluating four key variables with information on cause of death 1) multiple cause of death (MCD) codes, 2) underlying cause of death (UCD) codes, 3) abstractor cause of death summaries, and 4) narrative descriptions of the death investigation. MCD and UCD codes are mandatory elements of death certificates that assign causes of death using the ICD-10 coding scheme. Every death certificate contains one underlying cause of death and up to twenty additional multiple causes; the NVDRS includes data on UCD and up to 10 MCD codes. The abstractor cause of death summary comes from the culmination of evidence used to complete death certificates where the state-level NVDRS data abstractor assigns a brief and specific summary narrative of what caused the death. Narratives include a detailed description from the coroner/medical examiner and/or law enforcement investigations of the circumstances surrounding the death.

All undetermined intent deaths with an illicit drug-related UCD code (Y10-Y14) or at least one illicit drug-related MCD codes were included (Y10-Y14) (illicit drugs are defined below).

Abstractor cause of death summaries that mentioned alcohol or drugs as a cause of death were also included. Narratives were reviewed, and cases were included where the narrative suggests suicidal intent (e.g., "victim left a suicide note"), that the injury was self-inflicted (e.g., "victim shot themselves in the head") or intentional (e.g., "victim was seen jumping off of a bridge").

From the remaining causes of death, the following types of UCD and MCD codes were selected for further evaluation: those that could be potentially self-inflicted causes (e.g., Y20 - Hanging, strangulation and suffocation), drug poisoning deaths not due to illicit drugs (e.g., T45.0 - Poisoning by, adverse effect of and underdosing of antiallergic and antiemetic drugs), related to mental health (e.g., F31.9 - Bipolar disorder, unspecified), were unspecified (Y34 - Unspecified event), or were missing. For these causes of death, abstractor summaries and narratives were evaluated for each case. Cases were included if they met the summary or narrative criteria described above, or excluded if the narrative mentioned the victim was found as decomposed remains, partial remains, the case was a suspected accidental death, was part of an active homicide investigation, or if foul play was suspected. In total, there were 6,094 cases of undetermined intent included in the final sample.

Defining Substance-involved Deaths

Deaths were classified as alcohol-related if the MCD or UCD cause was alcohol (ICD-10 codes for alcohol overdose X45, X65, Y15), if the decedent tested positive for alcohol, or if the abstractor narrative assigned alcohol as a cause of death. Deaths were classified as drug-related if the MCD or UCD cause of death was an illicit drug (ICD-10 codes X40-X44, X60-X64, X85, Y10-Y14) or if the decedent tested positive for any of these substances. Illicit drugs included amphetamines or cocaine or opioids, and if abused inhalants (i.e., nitrous oxide or derivatives) were implicated as a cause of death in the summaries or narratives.

Substance-involvement in SIM deaths was determined by toxicology data provided in the NVDRS. However, the toxicology data are sometimes unavailable due to lack of testing. Missing toxicology data are not a major concern for drug-related deaths. Drugs are a highly lethal, common, and often obvious cause of suicide and deaths of undetermined intent. For example, drug poisoning deaths accounted for 16% of all SIM deaths in 2020. There are also multiple ways of coding drug deaths in the NVDRS, including toxicology, ICD-10 code, or the official abstractor determined cause of death as described above.

For an overwhelming majority of alcohol-related deaths, the direct cause is not alcohol poisoning, but another cause, such as firearms. However, many SIM deaths involve decedents consuming alcohol before their deaths (Kaplan, et al). Therefore, drug-related deaths are reported as the count of drug-related deaths as the numerator and all SIM deaths as the denominator. For alcohol-related deaths, statistics are reported with alcohol deaths as the numerator and all decedents tested for alcohol as the denominator. Overall, alcohol was tested in 57% of the sample (N=61,211), including 65.5% of AIANs (N=1,500), 52% of Blacks (N=3,729), and 57% of Whites (N=55,982).

Final Definition of SIM Variable

The final sample of SIM deaths was defined as those classified as suicides or undetermined intent deaths that were drug-related or resulted from a self-inflicted behavior. The dependent SIM variables were operationalized as rates or for all SIM deaths (i.e., SIM rate per 100,000) and for substance-involved SIM deaths (i.e., alcohol-related SIM, drug-related SIM, alcohol- and drug-related SIM per 100,000). Substance-involved SIM deaths were also used as a binary outcome for substance-involved versus not substance involved deaths.

SIM Sample Description

The final NVDRS sample included 107,729 SIM decedents. A majority died by suicide and were White. Table 3 shows the distribution by intent and race, including the sample sizes for each race.

Table 3. Distribution of NVDRS Death Type by Race, 2015-2020.

	AIAN		**Black**		**White**	
	N	*%*	*N*	*%*	*N*	*%*
Suicide	2168	94.6%	6597	92.2%	92870	94.5%

Undetermined Intent	123	5.4%	555	7.8%	5416	5.5%
Total	2291	2.1	7152	6.6	98286	91.2

Each of the 24 states included in the final sample recorded at least five SIM deaths for each racial group except for five states which recorded less than five AIAN deaths (Connecticut, New Hampshire, New Jersey, Rhode Island, Vermont) and one state that recorded less than five Black deaths (Vermont). Table 3 shows the distribution of the sample across states. Of the 24 states included in the sample, over one-third of the sample are from the top five states (Ohio, Michigan, North Carolina, Georgia, and Arizona). Certain states also account for significantly larger portions of the sample population by race. This likely reflects the population composition of each state. For example, the AIAN sample comes primarily from states with high AIAN populations (e.g., Arizona, Oklahoma, Alaska). Similarly, much of the Black sample comes from Georgia, Michigan, Ohio, North Carolina, and Virginia.

Table 4. Distribution of SIM Decedent Sample by State and Race.

	AIAN		**Black**		**White**		**Total**	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
AK	387	16.90%	22	0.30%	691	0.70%	1100	1.00%
AZ	447	19.50%	242	3.40%	6377	6.50%	7066	6.60%
CO	96	4.20%	193	2.70%	5885	6.00%	6174	5.70%
CT	0	0.00%	144	2.00%	2034	2.10%	2178	2.00%
GA	7	0.30%	1360	19.00%	6743	6.90%	8110	7.50%
KS	39	1.70%	126	1.80%	2676	2.70%	2841	2.60%
KY	14	0.60%	206	2.90%	4519	4.60%	4739	4.40%
MA	5	0.20%	183	2.60%	3505	3.60%	3693	3.40%
ME	15	0.70%	14	0.20%	1486	1.50%	1515	1.40%
MI	121	5.30%	913	12.80%	9055	9.20%	10089	9.40%
MN	131	5.70%	145	2.00%	3972	4.00%	4248	3.90%
NC	70	3.10%	765	10.70%	7465	7.60%	8300	7.70%
NH	1	0.00%	19	0.30%	1443	1.50%	1463	1.40%
NJ	1	0.00%	313	4.40%	3396	3.50%	3710	3.40%
NM	291	12.70%	46	0.60%	1565	1.60%	1902	1.80%
OH	8	0.30%	791	11.10%	9361	9.50%	10160	9.40%
OK	408	17.80%	195	2.70%	3882	3.90%	4485	4.20%
OR	75	3.30%	60	0.80%	4534	4.60%	4669	4.30%
RI	2	0.10%	27	0.40%	646	0.70%	675	0.60%
SC	12	0.50%	504	7.00%	4115	4.20%	4631	4.30%
UT	69	3.00%	38	0.50%	3684	3.70%	3791	3.50%
VA	16	0.70%	684	9.60%	5710	5.80%	6410	6.00%

VT	2	0.10%	4	0.10%	724	0.70%	730	0.70%
WI	74	3.20%	158	2.20%	4818	4.90%	5050	4.70%

Multidimensional Deprivation

The MDI is the primary independent variable. Social and material deprivation is a measurable variable based on theory. Townsend (1987) developed deprivation as a concept to analyze social conditions in the context of increasing inequality in the 1980s. In suicidology, the concept of deprivation is traced earlier to Durkheim, who recognized that suicide rates are higher in areas with fewer socio-economic resources and decreased social integration (Berkman et al., 2000; Durkheim, 1897). Using deprivation to study social and health outcomes is well established in empirical research and as a method to guide governmental approaches to population health (Fu et al., 2015; Glassman, 2019; Thibodeau et al., 2018). Twenty-six countries and the European Union use multidimensional deprivation measures to provide a comprehensive description of socio-economic challenges faced by their populations (Glassman, 2019).

The MDI is a good fit for studying the relationship between the socio-economic context and SIM rates. It is a recently released area-based measure of multidimensional deprivation from the U.S. Census. It provides a metric interpreted as the percent of a population deprived on at least two dimensions representing social and material deprivation.

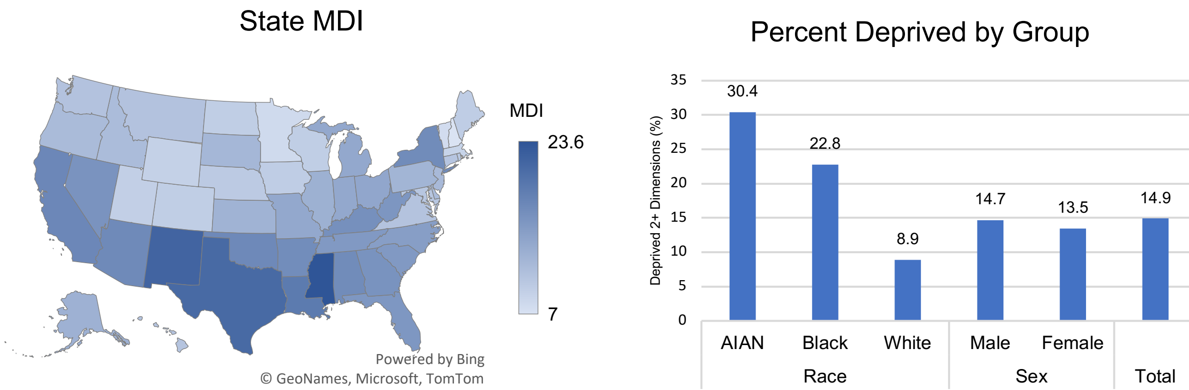
Measures of multidimensional deprivation are commonly used internationally, yet the MDI is a new measure in the U.S. context. It was developed to be on par with those used in other high-income countries for use in scholastic research following the demonstrated usefulness of similar measures in other countries (Glassman, 2019). A recent U.S. Census report on the MDI measures promotes using these data to explore relationships between the MDI and health outcomes. It provides a more nuanced understanding of deprivation by considering the multiple dimensions by which one can be disadvantaged, material and non-material. Table 5 shows the MDI measure's dimensions and how they are defined.

Table 5. Multidimensional Deprivation Index Dimensions Defined.	
Dimensions	**How Dimensions are Measured**
Standard of living	Living below poverty threshold (defined by U.S. Census Official Poverty Measure)
Education	Aged 19 or older without a high school diploma or GED
Health	< age 65 and lacked health insurance; > age 65 and lacked health insurance or at reported least 2 disabilities
Economic security	Unemployed, or: < age 65 average household working < 20 hours per week; >age 65 average, weeks worked per year < 26, or minimal retirement income
Housing quality	Housing unit with > 2 people per bedroom or lived in an emergency or transitional shelter
Neighborhood quality	Multidimensional measure of census block group neighborhood environment quality, 1-100 (scaled least-most deprived); deprived = area score > 90
(Glassman, 2021)	

Though the MDI is a good fit for studying the relationship between the socio-economic context and SIM rates, it has not yet been attempted. It includes multiple social determinants hypothesized to be significantly associated with SIM and has the support of the lead scientist for MDI development at the U.S. Census Bureau (personal communication).

In the MDI, deprivation level is assigned to a group or geographical unit (i.e., state) based on whether a population meets the metric for deprivation: being deprived on at least two of six dimensions. The composite overall MDI score reported is a headcount ratio, representing the total number of people deprived divided by the total population. This is reported as a percent MDI, representing the portion of the population living in multidimensional socio-economic deprivation. The distribution of MDI in the U.S. population varies by geographic and demographic group (Figure 9). This is an expected outcome correlated with trends in the distribution of poverty (according to the official poverty measure) and the differential distributions of resources and opportunities, especially by race.

Figure 9. Distribution of MDI by State and Socio-Demographic Group, 2019.



MDI Independent Variable Construction

The MDI sample included values provided by the U.S. Census for years 2015 through 2020 from the 24 states included in the NVDRS, resulting in 144 state-year observations. The range of MDI values was 7% to 22%. MDI values were used as both a continuous variable and variables grouped by quantiles based on the distribution of all state-year MDI values. Primarily analyses used MDI quartiles defined by the 25th, 50th, and 75th percentiles (Table 6). In some instances, models were not estimateable due to sample size restrictions; therefore, terciles (defined by the 33rd percentile = 14.7 and 66th percentile = 16.0%) and a bi-level variable above and below the median MDI ($\widetilde{M}$ = 12.5%), were used.

Table 6. MDI quartile Variable definition and associated States.

Quartile	States	Range
1	CO, CT, MA, ME, MN, NH, RI, UT, VA, VT, WI	7.0% - 10.8%
2	AK, CO, CT, KS, ME, MI, NJ, OH, OR, RI, UT, VA	10.8% - 14.2%
3	AK, AZ, GA, KY, MI, NC, OH, SC	14.3% - 16.4%
4	AZ, GA, KY, MI, NC, NM, OK, SC	16.5% - 22.1%

Statistical Procedures

The following subsection details the statistical techniques used to complete analyses for each specific aim. All regression analyses were conducted in R Version 4.2.2, χ^2 and ANOVA tests were conducted in SPSS Version 28.

Analysis Used to Address Aim 1

To address questions under aim 1 (describe the socio-demographic profile of SIM decedents across categories of MDI), χ^2 tests of independence were used. These tests examined the association between socio-demographic characteristics within and between categories of MDI and race. Tukey HSD post-hoc tests with Bonferroni corrections evaluated between and within group comparisons. These included within race across categories of MDI, and within categories of MDI between races. P-values were evaluated at the $\alpha = 0.05$ level. The purpose of conducting χ^2 tests was to evaluate potential differences in the proportion of SIM decedents within and between categories of MDI (e.g., low MDI = quartile 1, high MDI = quartile 3).

Aim 1 was also addressed using ANOVA analyses that were conducted to test for significant differences in mean substance-involved SIM rates across categorical levels of MDI. Quartiles of MDI were preferred, but where quartiles were not able to be estimated, MDI terciles and median-split groupings (low/high) were used. Omnibus one-way models tested SIM rates across MDI categories. Two-way ANOVAs included SIM rates, MDI, geographic region, and an interaction between MDI and region. ANCOVA models of SIM rates and MDI category controlled for geographic region. If omnibus tests were significant, post-hoc tests were used to make comparisons between MDI categories using Bonferroni corrections. Significance is reported at $\alpha = 0.05$.

Analysis Used to Address Aim 2

Aim 2 was to estimate and describe age-standardized SIM rates. Estimates of state-year SIM rate were made from the count of SIM deaths in the NVDRS divided by the state-year population (generating the crude rate). State-year estimates were age standardized using U.S. standard millions population from 2000 with data from the National Cancer Institute Surveillance, Epidemiology, and End Results Program (SEER). The following direct age standardization equation was used, where θ_i is the crude SIM rate in the *i*th age group and π_i is the standard population proportion for the *i*th age group.

$$Age\ standardized\ Rate\ = \sum \theta_i \, \pi_i$$

Age-standardized and age-specific rates incidence rates were estimated using the Surveil package in R. The rate estimation methods in the Surveil package is most appropriate for rare events, thus, was preferred for incidence rate estimation over the study period, especially for race-specific rates. These rates were generated using a Poisson model and produced estimates with 95% credible intervals for rates and annual percent change. The age-standardization method used U.S. standard millions.

Analysis Used to Address Aim 3

The single-level aim 3 was to model the relationship between SIM rate and MDI. Multiple statistical techniques were used to explore the relationship. These included linear regression, ANOVA, linear regression of differences between time points, logistic regression with predicted probabilities, and risk attribution estimates. Each type of analysis is described below.

Linear Regression. linear regressions were used to estimate the relationship between state-year SIM rate and MDI as bivariate models. Regressions were completed for all SIM deaths and for those for each type of substance-involvement. In the process of checking assumptions for linear regression, the scatter and diagnostic plots suggested a curvilinear relationship between SIM rate and MDI. Linear and polynomial regression models were compared. Based the distribution of residuals and AIC/BIC values, the quadradic linear regression models provided the best fit for all iterations of the SIM rate and MDI relationship. The final regression model was:

$$SIMRate_i = \ \beta_0 \ + \ \beta_1 \, (MDI_i) + \beta_2 (MDI_i)^{\mathbf{2}} + u_i$$

Linear Regression of Differences Between Time Points. To analyze the change in the relationship between SIM rate and MDI, comparisons were made between 2015 and 2020 within low and high categories of MDI. These models analyzed the difference in changes in SIM rate relative to MDI between the years 2015 and 2020. Where Z_i are the unobserved time-invariant state-specific characteristics, the population regression models for the two time periods are:

$$SIMRate_{i2015} = \beta_0 + \beta_1 MDI_{i2015} + \beta_2 Z_i + u_{i2015}$$
$$SIMRate_{i2020} = \beta_0 + \beta_1 MDI_{i2020} + \beta_2 Z_i + u_{i2020}$$

The difference between these two models was then regressed:

$$SIMRate_{i2015} - SIMRate_{i2020} = \beta_1(MDI_{i2015} - MDI_{i2015}) + u_{i2015} - u_{i2020}$$

This method accounts for time-invariant characteristics that differ across states (Z_i), these models generate coefficient estimates that are robust to possible omitted variable bias based on those unobserved characteristics.

Logistic Regression. Logistic regression models were used to differentiate substance-involved deaths (Y = 1) versus those that did not involve substances (Y = 0). Two models were estimated in a forward stepwise analysis. The base model included MDI and race, the second model included an MDI and race interaction term. The population logistic regression function for the base model was:

$$P\left(Y = 1 \middle| X_{MDI_i} + X_{Race_i}\right) = logit\left(P(Substance = 1|MDI_i + Race_i)\right) = \frac{exp(\beta_0 + \beta_1 MDI_i + \beta_1 Race_i)}{1 + exp(\beta_0 + \beta_1 MDI_i + \beta_1 Race_i)}$$

and for the model with the interaction term:

$$P\left(Y = 1 \middle| X_{MDI_i} + X_{Race_i} + X_{MDI_i} \times X_{Race_i}\right) = logit\left(P(Substance = 1|MDI_i + Race_i + MDI_i + Race_i \times MDI_i)\right) = \frac{exp(\beta_0 + \beta_1 MDI_i + \beta_2 Race_i + \beta_3 MDI_i \times Race_i)}{1 + exp(\beta_0 + \beta_1 MDI_i + \beta_2 Race_i + \beta_3 MDI_i \times Race_i)}$$

Exponentiated regression coefficients (odds ratios), standard errors, and p-values at $\alpha = 0.05$ are reported. The predicted probability of a substance-involved death (Y=1) at mean MDI was also estimated for each type of substance-involved death and each race with 95% confidence intervals.

$$P(Y = 1|\overline{X_{MDI_i}} + X_{Race_i} + \overline{X_{MDI_i}} \times X_{Race_i})$$

Measures of Racial Inequality in SIM Rate. Multiple measures were used to estimate inequality in SIM rates between racial groups and MDI categories over the study period. Measuring inequality between MDI quartiles and race by MDI quartiles provides estimates comparing populations potentially overburdened by SIM risk to a reference population. These provide different perspectives on the magnitude of the disparity in SIM rates between two groups (Donegan, 2022). The three measures of pairwise inequality were generated include: incidence rate ratio (IRR), excess cases (EC), and proportion attributable risk (PAR) all with 95% credible intervals. IRR is the ratio of the SIM rate for the disadvantaged group (numerator) compared to the advantaged group (denominator) where an RR of 1.0 indicates equal rates, an RR greater than 1.0 indicates increased risk for the disadvantaged group (numerator), and an RR less than 1.0 indicates a decreased risk for the disadvantaged group. The PAR is the SIM rate difference between two groups expressed as a percent, it is the cumulative excess cases expressed as a fraction of group risk. It represents the fraction of SIM risk in the disadvantaged population that would be removed if the disadvantaged population's SIM rate were equal to that of the advantaged population.

Pairwise measures of inequality provide important information about the relative contribution of MDI to SIM risk across groups. However, they do not provide estimates of differences across multiple groups. Theil's T Inequality Index provides summary measures of differences across multiple groups, it measures the extent to which groups are overburdened. When groups share equal risk Theil's T = 0, and increases as rates for any two groups diverge. Rates were estimated using the surveil package in R.

Analysis Used to Address Aim 4: Multi-level Modeling

These data include SIM rate and MDI observations for each year for each state. This represents a longitudinal nested data structure with repeated measures (annually) for each state; states are also clustered within regions. In analysis these data take the structure of state-year (level 1), state (level 2). Year was also added as a level 2 covariate in one model.

Multi-level modeling approaches are best suited to assess data with this type of structure because they can estimate random intercepts and random slopes. In a single-level regression model, the slope is common to all observations. However, when data are clustered into larger groupings—in this analysis multiple annual SIM rates and MDI levels within states—it is possible that each state could have different mean SIM rates when MDI = 0 (i.e., the intercepts could be different). To accommodate this, we estimate random intercept models which allow for each level 2 grouping (state) to have a different intercept. It is also possible that the effect of MDI on SIM rate (i.e., the coefficients representing the slopes) could vary by state, thus we estimate random slopes models that allow the intercepts and coefficients for each state to differ. Modeling these data using a multi-level approach addresses the fact that there are relationships among state-year observations for SIM rate (the dependent variable) even after accounting for MDI (the independent variable). In other words, it is reasonable to assume that there would be correlated within and across states.

Interclass correlation (ICC, ρ_I) was estimated for null models of SIM rate by state. This measure is the correlation among annual SIM rates within state. ICC is a measure of the proportion of the variation in individual SIM rate observations accounted for by state and region. Higher values indicate that the multilevel data structure has a greater impact on SIM rate.

Considering the nested data structure, two-level Poisson multi-level count models were estimated for random intercepts and random slope models which included both random intercepts and random slopes. Poisson models were offset by the state-year population at risk resulting in the outcome being modeled as a rate. The Poisson mixed random effects model was:

$$log(y_{ij}) = \gamma_{00} + \gamma_{01}x_{ij} + log(E_{ij}) + U_{0j} + U_{1j}x_{ij} + \varepsilon_{it}$$

$$Level\ 1: log(y_{ij}) = \beta_{0j} + \beta_{1j}x + \varepsilon_{it}$$
$$Level\ 2: \beta_{0j} = \gamma_{00} + U_{0j}$$
$$\beta_{1j} = \gamma_{10}$$

Where Y_{ij} is the conditional expectation of the SIM mortality rate for *i* state-year MDI observation in the *j* state. The model components are γ_{00}, which is the average intercept value across states (i.e., it is a fixed value across states), $\gamma_{01}x_{ij}$ is the level 1 fixed-effect slope related to state-year MDI observations (x_{ij}), E_i is the state-year population, U_{0j} is the state-specific effect on the intercept (i.e., it varies across states), and U_{1j} is the state-specific variation in the relationship between MDI and SIM rate. Overall, $\gamma_{00} + \gamma_{01}x_{ij}$ are the fixed effect components, and $U_{0j}+U_{1j}+\varepsilon_{ij}$ are the random effects.

Random intercept models and mixed random effect models were evaluated for best model fit using AIC/BIC criteria. Model comparisons were also made using ANOVA. All multi-level analyses were estimated using the nlme package in R.

CHAPTER 4: RESULTS

Results of a descriptive nature are presented first. Descriptive statistics include sociodemographic characteristics of SIM decedents, key indicators of substance involvement, and the distribution of these factors across race and levels of MDI. A description of general findings on MDI and SIM rates is also presented. These results are followed by findings from the single-level analyses on the relationship between SIM rates and MDI and, finally, results from multi-level modeling.

Characteristics of SIM Decedents

Sample characteristics followed an expected pattern based on known population mortality trends. The sample consisted primarily of male (76.7%), White (91.2%), and suicide (94.3%) decedents. The mean age was youngest among AIANs (35 years), followed by Blacks (38 years) and Whites (49 years). Accordingly, younger age groups comprised a larger portion of the sample among AIANs and Blacks, while older age groups comprised a larger portion of the White sample.

A breakdown of decedent sociodemographic characteristics by race is provided in Table 7. The most commonly reported relationship statuses were married/partnered (30.5%) or never married (34.8%) and divorced (22.8%). More than half of the sample had a high school degree or less (54.8%), about one-quarter had a high school degree or some college (25.2%), and about one-fifth had a bachelor's degree or higher (18.1%). The most reported occupational sectors were construction (12.5%), manufacturing (11.6%), and not in the workforce (11.6%).

Table 7. Characteristics of SIM Decedents, 2015-2020.

	AIAN		**Black**		**White**	
	N	*%*	*N*	*%*	*N*	*%*
Sex						
Female	575	25.1%	1533	21.4%	22970	23.4%
Male	1716	74.9%	5619	78.6%	75316	76.6%
Age Group						
15-24	611	26.7%	1764	24.7%	10625	10.8%
25-34	730	31.9%	1925	26.9%	15222	15.5%
35-44	410	17.9%	1241	17.4%	15653	15.9%
45-54	280	12.2%	979	13.7%	18868	19.2%
55-64	159	6.9%	707	9.9%	18573	18.9%
65-74	58	2.5%	342	4.8%	10583	10.8%
75+	43	1.9%	194	2.7%	8762	8.9%
Marital Status						
Never Married	1269	55.4%	4251	59.4%	32015	32.6%
Married/partnered	437	19.1%	1422	19.9%	30991	31.5%
Divorced	288	12.6%	865	12.1%	23396	23.8%
Education Attainment						
High school or less	1679	73.3%	4397	61.5%	52973	53.9%
High School or some college	474	20.7%	1838	25.7%	24833	25.3%
Bachelor's degree or higher	112	4.9%	758	10.6%	18667	19.0%
Occupational Industry						
Construction	401	17.5%	431	6.0%	12623	12.8%
Manufacturing	134	5.8%	771	10.8%	11560	11.8%
Not in workforce	469	20.5%	1016	14.2%	11025	11.2%
Military Status	154	6.7%	981	13.7%	16886	17.2%

Of all SIM deaths, 43.5% involved alcohol or drugs. Of those, 35.9% involved only alcohol, 19.7% involved only drugs, and 19.0% involved alcohol and drugs. Overall, 34.2%

(n=20833) of decedents with alcohol toxicology available had a positive BAC. Table 8 includes a breakdown of substance use involvement by race, indicating significant differences produced by χ^2 tests with posthoc group comparisons ($p<0.05$). The prevalence of alcohol-related deaths was significantly higher among AIAN decedents but comparable among Blacks and Whites. Among those with BAC toxicology, the proportion of those legally intoxicated (BAC>0.08mg/dL) was also significantly higher among AIANs.

Information on drug involvement was not limited in the same manner as alcohol involvement; thus, out of the entire sample, drugs were involved in 24.2% of deaths. The prevalence of drug-related deaths was comparable among AIANs and Whites but was significantly lower among Blacks. Among those tested for each drug, positivity rates were highest for opioids (27.2%, n =14288), followed by amphetamines (11.4%, n=5618), and cocaine (6.8%, n=3414). Opioid positivity was significantly higher among Whites versus other races and cocaine positivity higher among Blacks versus others. The positivity rate for amphetamines was significantly different across all races. The portion of deaths that were both alcohol and drug-related also varied considerably between all racial groups, but the prevalence was highest among AIANs.

Table 8. Prevalence of Substance Use Involvement among SIM Decedents, 2015-2020.

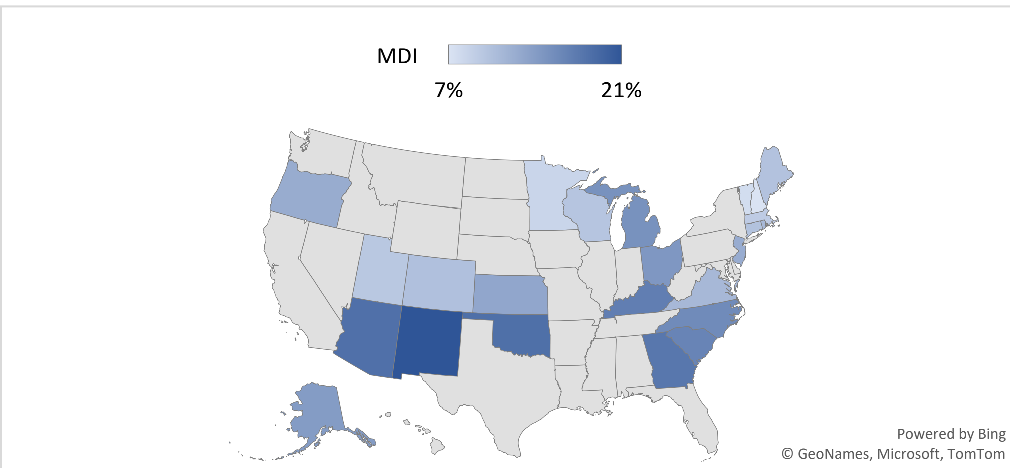
	AIAN		**Black**		**White**	
	N	*%*	*N*	*%*	*N*	*%*
Alcohol-related	899	58.6% $_a$	1971	49.4% $_b$	28921	49.2% $_b$
BAC >0.08 mg/dL	591	41.2% $_a$	721	19.0% $_b$	13742	24.7% $_b$
Mean BAC mg/dL among positives	0.17		0.13		0.15	
Drug-related	599	26.1% $_a$	1480	20.70% $_b$	24013	24.4% $_a$
Amphetamine positivity	258	11.3% $_a$	228	3.2% $_b$	5132	5.2% $_c$
Cocaine positivity	54	2.4% $_a$	487	6.8% $_b$	2873	2.9% $_a$
Opioid positivity	182	8.4% $_a$	642	10.1% $_a$	13464	15.0% $_b$
Alcohol- and drug-related	341	14.9% $_a$	661	9.2% $_b$	9977	10.2% $_c$

Subscripts in each row denote significant differences in the proportion between races; within each row, cells with the same subscript are not statistically different.

Multidimensional Deprivation Index

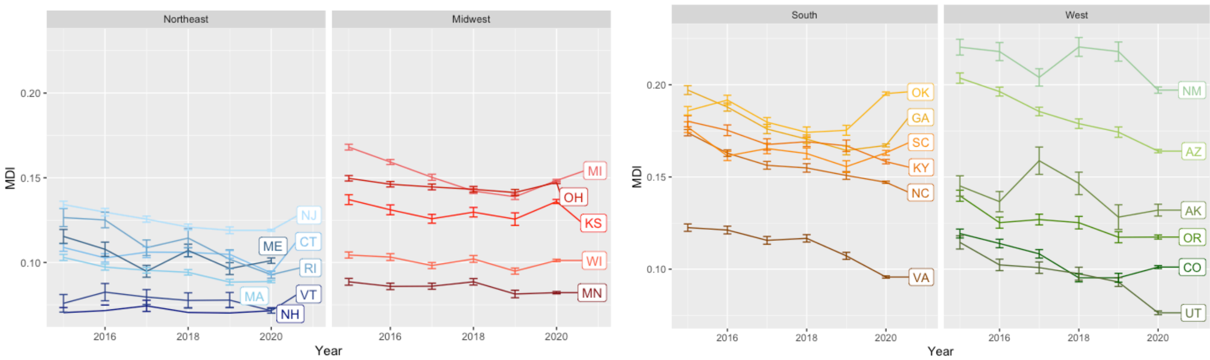
Among states in the sample, the mean MDI was 13.1%, indicating that on average, 13.1% of state populations were deprived on at least two MDI dimensions. Figure 1 maps the mean MDI for each state over the study period. For many states, there was significant variation in MDI within states and between states over the study period. The lowest recorded MDI was in New Hampshire in 2019 (7.0%), and the highest was in New Mexico in 2018 (22.0%). Figure 2 depicts trends in MDI for each state with 95%CIs, grouped by region over the study period.

Figure 10. State Mean MDI, 2015-2020.



MDI values tended to be more similar within region, though there was also significant variation between many states within region. Some states also experienced significant changes in MDI over time, while others remained statistically stable. Among states included in the sample, the lowest mean MDI within region was in the Northeast (9.8%, 95%CI: 9.5%, 10.1%), and the highest value was in the West (14.4%, 95%CI: 13.7%, 15.1%).

Figure 11. State-Year MDI and 95%CI by Region, 2015-2020.



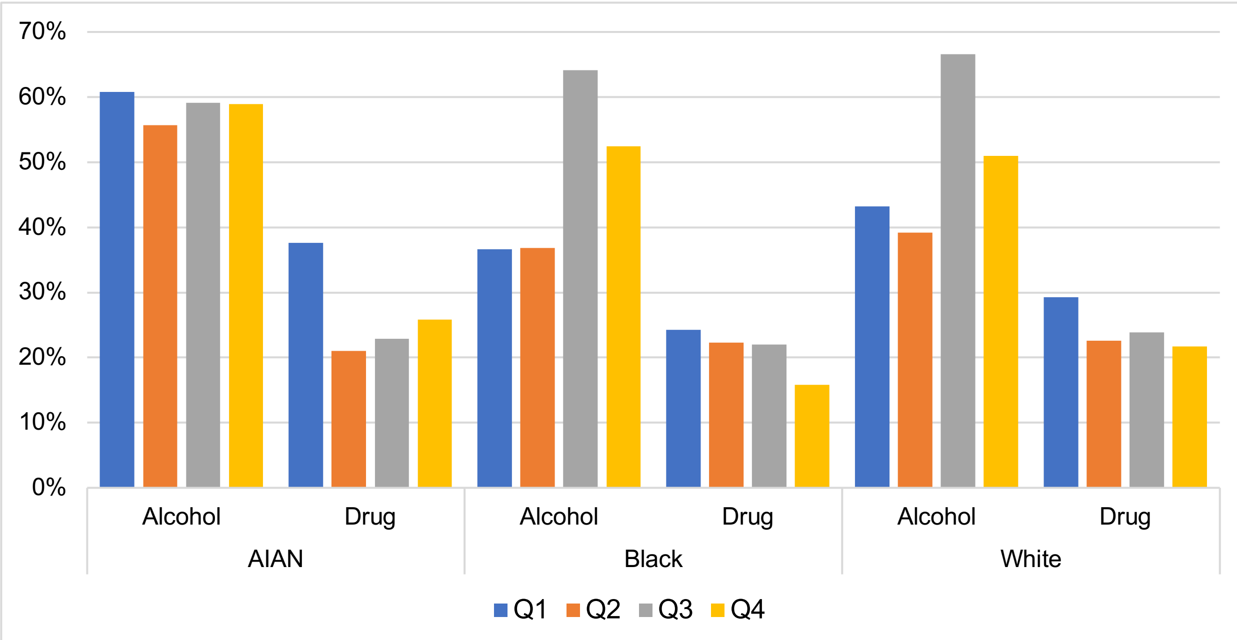
Characteristics of SIM Decedents Within Levels of MDI

About one-quarter of the SIM decedent sample was represented in each MDI quartile. However, the mean MDI was significantly different between AIANs (15.8%), Blacks (14.7%), and White decedents (13.8%). Across quartiles of MDI, the proportion of each racial group in the quartiles was significantly different for all combinations except the prevalence of AIANs and Blacks in the lowest quartile, which was comparable. Overall, AIANs were overrepresented in areas with the highest levels of deprivation, and Whites were overrepresented in areas with the lowest levels.

Substance Involvement Among SIM Deaths by MDI

The prevalence of alcohol-related deaths by race differed significantly in the lowest versus highest quartiles, representing areas with the lowest and highest levels of deprivation. However, there was different patterns by race (figure 12). The proportion of alcohol-related deaths was relatively constant across MDI quartile for AIANs. Among Blacks and Whites, alcohol-related deaths were substantially more common at high MDI versus low MDI. For drug-related deaths among AIANs the proportion was highest at the lowest levels of MDI, and similar for all other quartiles. Though the absolute differences in the proportion of deaths involving dugs were small, for Blacks the proportion of deaths involving drugs was significantly higher in in the fourth MDI quartile versus the first; the opposite was true for drug deaths among Whites, with the proportion being significantly higher in the first versus fourth quartile.

Figure 12. Prevalence of Alcohol- and Drug-related Deaths by MDI Quartile and Race.



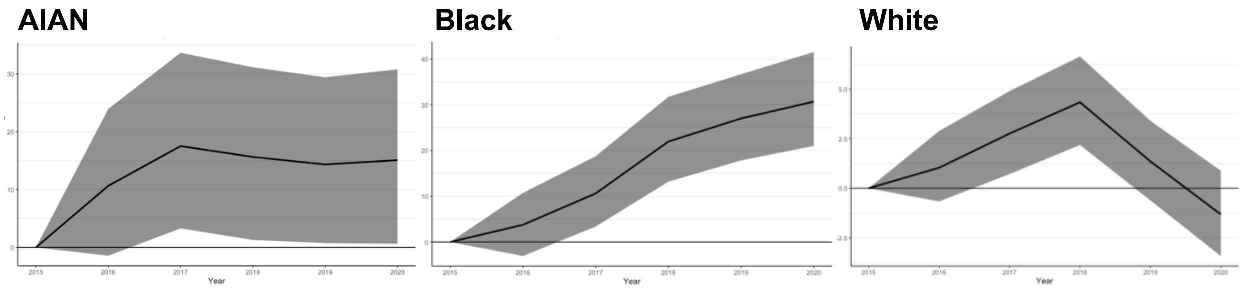
SIM Rates

Age-standardized SIM rates per 100,000 for the sample over the study period was 20.8. The highest per 100,000 rate was in 2018 at 21.5, and the lowest rates were 20.4 in 2015 and 2020. SIM rates followed expected trends across races over the study period. On average, rates per 100,000 were significantly higher among AIANs (29.6) relative to Blacks (8.66) and Whites (19.2).

Changes in SIM Rates Over Time

Comparing SIM rates between the beginning and end of the study period (2015 and 2020), there were significant increases for Blacks but not for AIANs or Whites. Results from annual percent change models found significant changes in the per-period percent change in SIM rate for all races and an overall significant increase in SIM rates (cumulative percent change) for AIANs and Blacks, but not Whites (Figure 13). The cumulative percent change in SIM rate over the study period was 15.1% (95%CI:0.6%,30.8%) for AIANs, 30.7% (95%CI: 21%, 41.5%) for Blacks, and -1.3% for Whites (95%CI: -3.4%, 0.9%).

Figure 13. Cumulative Percent Change in SIM Rate by Race, 2015-2020.



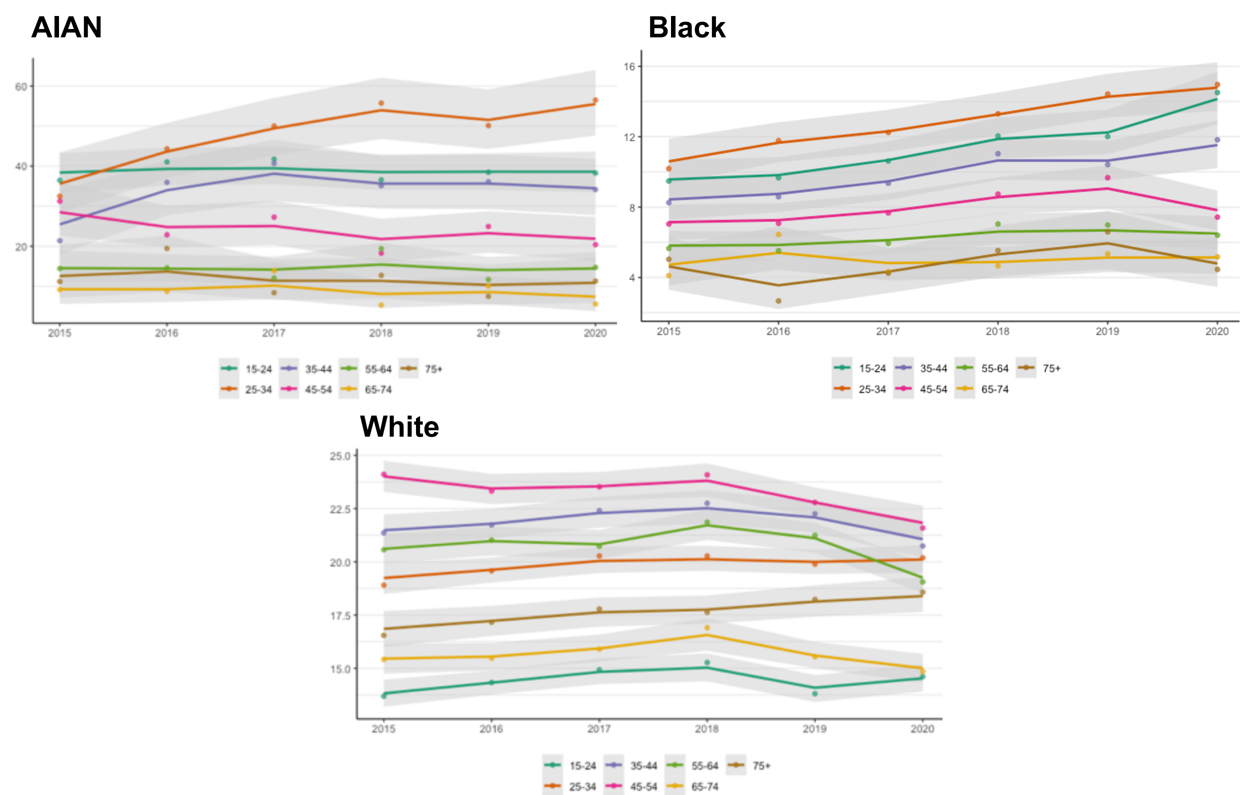
Among AIANs, the annual percent change in SIM rate was positive for all years except 2018 and 2019, ranging from -1.5% (95%CI: -11.0%, 8.0%) in 2018 to 10.6% (95%CI: -1.0%, 24.0%) in 2016. Age group stratified cumulative percent change models indicated that overall changes in SIM rate were attributable to rate changes in certain age groups. Fluctuation in the annual percent change was primarily due to significant increases among those 25-34 (cumulative percent change 58.0%) and 35-44 (cumulative percent change 49.0%), in contrast rates in other age groups did not change significantly.

The annual percent change in SIM rate among Blacks increased consistently over the study period; it was positive for all years and ranged from 3.0% (95% CI: -3.4%, 10.0%) in 2020 to 10.0% (95% CI: 3.79%, 18.0%) in 2018, though there was not a significant change in rates year-to-year. This overall trend is primarily driven by increasing SIM rates among Black people in younger age groups, 15-24 (cumulative percent change = 48.0%), 25-34 (cumulative percent change = 40.0%), and 35-44 (cumulative percent change = 37.0%).

For Whites, rates increased and then decreased but SIM rates were not significantly different in 2015 than in 2020. However, the annual percent change was significantly higher in 2018 (2.0% 95% CI: -0.2%,3.4%) relative to 2020 (-3.0% 95%CI:-0.2%,-0.8%). Age-stratified cumulative percent change models showed significant increases in SIM among Whites in age groups 15-24 (5.0%) and 75+ (9.0%). However, these increases only occurred in specific age-year subsets, ages 15-24 in years 2017 and 2018, and ages 75 and older after 2018. There were decreases in the annual percent change in SIM rates after 2019 for Whites in all other age groups except 25-34, and there were significant decreases from 2018 to 2020 among those 35-44, 45-54, and 55-64.

The differing rate and absolute change in SIM rates within age groups should also be contextualized within age group-specific rates. There are significant differences in SIM rates across age groups. The highest overall SIM rates are among ages 45-54 and the lowest among 15-24. The per 100,000 rate trends in these two groups moved in opposite directions, with the 45-54 age group ranging from the nadir of 22.4 in 2020 to the high of 25.1 in 2015, and in the 15-24 age group ranging from the nadir of 15.2 in 2015 to the high of 16.7 in 2020.

Figure 14. Age-Specific SIM Incidence Rates and 95% CI, by Age Group and Race.



However, the whole sample trends most reflect Whites versus other groups. Figure 14 shows SIM rate trends by age group and race. Significant differences were identified in the age group composition of SIM decedents across races. Among AIANs and Blacks, the highest rates were in the 25-34 age group, followed by the 15-24 age group. For White decedents, the highest rates were in middle age, among the 35-44 and 45-54 age groups. The lowest rates followed a similar pattern by race, with the 65-74 and 75 years and older groups with the lowest rates among AIANs and Blacks, but Whites ages 15-24 had the lowest rates.

SIM Rates and MDI

The mean SIM rate in the lowest MDI quartile was 19.4 per 100,000, compared to the mean rate in the highest quartile of 23.7 per 100,000. The SIM rate was significantly higher across all years in the highest MDI quartile versus the lowest (table 9). In the lowest MDI quartile, the SIM rate ranged from 17.6 in 2015 to 20.8 in 2018. The range in the highest MDI quartile was from 21.7 in 2015 to 26.3 in 2019.

Table 9. Age-standardized SIM rates per 100,000 by Low and High MDI quartiles, 2015-2020.

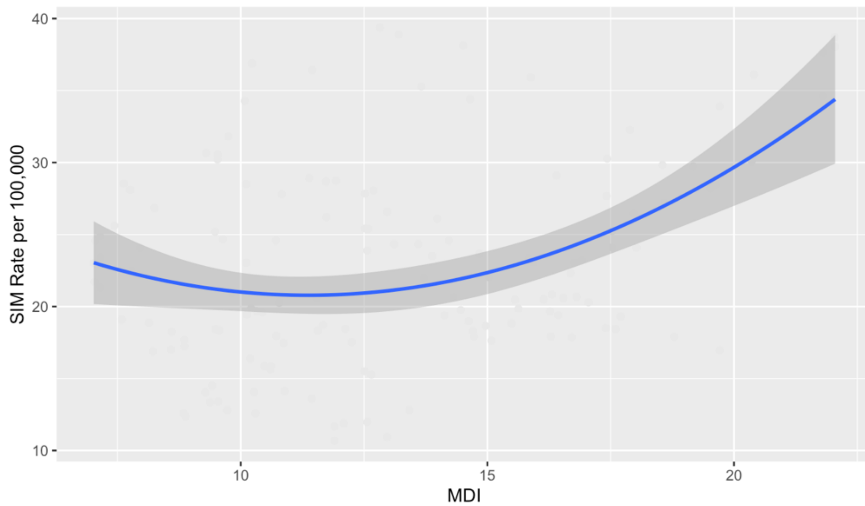
	Quartile 1		Quartile 4	
Year	**Rate**	**95%CI**	**Rate**	**95%CI**
2015	17.6	16.9, 18.3	21.7	21.2, 22.2
2016	18.9	18.3, 19.5	23.7	23.0, 24.4
2017	19.9	19.3, 20.4	23.3	22.7, 24.0
2018	20.8	20.3, 21.4	25.1	24.5, 25.8
2019	20.0	19.6, 20.5	26.3	25.4, 27.4
2020	19.3	18.8, 19.8	22.2	21.3, 23.1

When initially exploring the relationship between SIM rate and MDI, a curvilinear relationship was observed in both scatterplots and diagnostic plots for linear regression. This output suggested that a polynomial function may better fit the data. There was a significant relationship between the state-year SIM rate and state-year MDI (each coefficient had a $p<.05$). The best model fit (lowest AIC/BIC values) was with a quadratic function (versus linear) as the magnitude of the relationship changed as values increased (Figure 15). The estimated quadratic regression function was:

$$\widehat{SIMRate} = 36.21 + -2.71(MDI_i) + 0.12(MDI_i)^{\mathbf{2}}$$

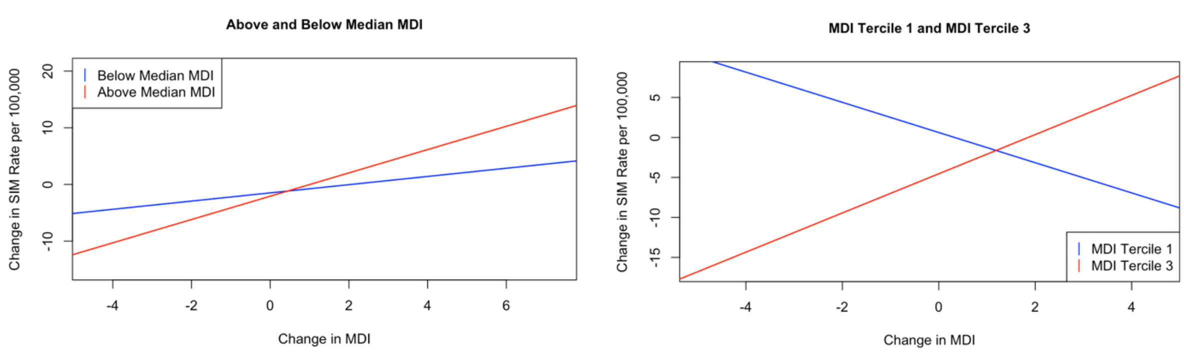
Beginning around the sample mean of MDI, the steepness of the slope in the modeled relationship between SIM rate and MDI begins to increase. For example, at the theoretical value when MDI = 0, the rate of change $(\widehat{\beta_0})$ is -2.7, at mean MDI the rate of change is 0.64, at an MDI of 18% the rate of change is 1.6. This indicates that SIM rates increase as the proportion of the population living in socio-economic deprivation increases above the sample mean.

Figure 15. Age-Standardized SIM Rate and MDI with 95%CI, 2015-2020.



Considering that SIM rates and MDI varied significantly over the study period, differences in SIM rate and MDI were estimated comparing 2015 and 2020. Models were estimated within low and high MDI groups using below and above median MDI and low and high terciles (quartiles could not be estimated). These models provide estimates of the relationship between SIM and MDI based on how they changed from 2015 to 2020. These estimates are robust to time-invariant characteristics that differ across states. Figure 16 shows the regression of SIM rate on the difference in MDI rate between 2015 and 2020.

Figure 16. Changes in SIM Rate and MDI Group between 2015 and 2020.



These models were positive and significant ($p<0.05$) for high MDI observations: above the median[1] and the highest tercile[2] (i.e., states with higher levels of deprivation). Results suggest that an increasing percent of the population living in deprivation is associated with a growing SIM rate between 2015 and 2020 in areas with the highest levels of deprivation. Regressions for observations below the median were not significant. For those in the lowest tercile of MDI,[3] (those with the lowest levels of deprivation) the relationship was significant ($p<0.05$) but negative, suggesting that increasing MDI from 2015 to 2020 was associated with decreasing SIM rate.

Measures of Inequality in SIM

Measures of inequality in SIM rate between groups were estimated. This analysis highlighted both trends over the study period and absolute SIM rate inequality within MDI tercile 1 (low MDI) and tercile 3 (high MDI), overall and between race groups. Comparing high MDI to low MDI, the SIM rate difference between the two groups increased significantly over the study period indicating an increasing disparity over time. Cumulatively from 2015 through 2020, there were 4,672 (95%CI: 4,151, 5,193) excess SIM deaths in high versus low MDI areas. The proportion attributable risk (PAR) value implied that 13% (95%CI: 0.12,0.14), of the risk for SIM in the high MDI areas would be removed if the SIM rate were the same as in low MDI areas.

The increasing inequality trend between high and low MDI areas is also supported by findings for Theil's T Inequality Index which was used to measure inequality in SIM rate between races. This measure is a summary of inequality for all three race groups that reflects the extent to which certain race groups are overburdened by SIM. Values increase from zero as the inequality in SIM rate between any two race groups diverge from the expected value based on the race-specific population proportion. Theil's T values for racial inequality in SIM rates within

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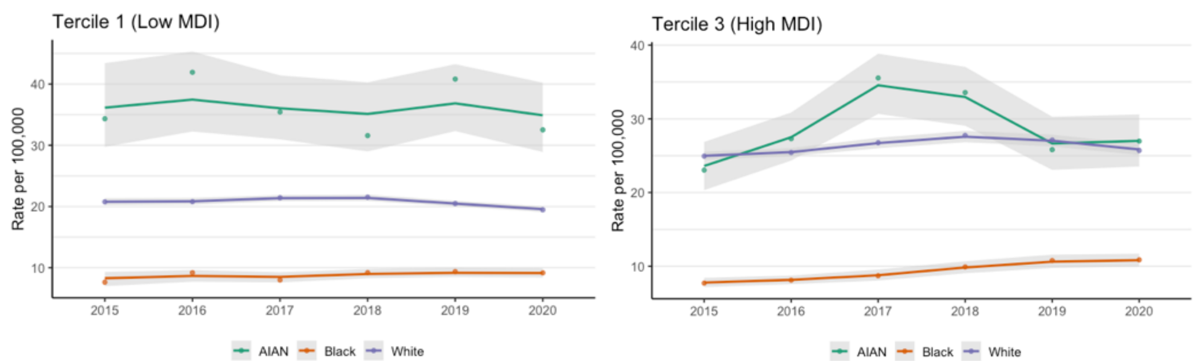
[1] Above Median MDI: $\widehat{SIMRate}_{i2015} - SIMRate_{i2020} = -2.07 + 2.06(MDI_{i2015} - MDI_{i2020})$
[2] MDI Tercile 3: $\widehat{SIMRate}_{i2015} - SIMRate_{i2020} = -4.537 + 2.45(MDI_{i2015} - MDI_{i2020})$
[3] MDI Tercile 1: $\widehat{SIMRate}_{i2015} - SIMRate_{i2020} = 0.622 - 1.90(MDI_{i2015} - MDI_{i2020})$

both low and high MDI terciles were >1, reflecting the obvious racial inequality (figure 17). In the group with the lowest levels of deprivation, there was a significant increase in racial inequality in SIM rate between 2015 and 2017, which then leveled off. In the states with the highest levels of deprivation, there was a significant decrease in inequality between races from 2017 through 2020.

Figure 17. Trends in Race-Specific SIM Rates in Tercile 1 and Tercile 3.



Measures of pairwise inequality between specific race combinations were also produced. Estimates of cumulative pairwise inequality over all study years is presented in Table 10; this is the relative magnitude of inequality between each combination of two races, the first race listed is the disadvantaged group and the second race listed is the reference group. This reflects the higher burden of SIM among AIANs relative to all other races for low and high terciles. However, the relative racial inequality was significantly lower in high MDI areas.

Table 10. Cumulative Measures of Pairwise Racial Inequality in SIM and 95% CI, 2015-2020.

	Tercile 1		Tercile 3	
	Cumulative Excess Cases	*PAR*	*Cumulative Excess Cases*	*PAR*
AIAN v. White	184 (145, 226).	0.42 (0.37, 0.48)	111 (41, 183)	0.08 (0.03, 0.13)
AIAN v. Black	327 (287, 369)	0.75 (0.73, 0.78)	880 (808, 950)	0.68 (0.66, 0.7)
White v. Black	19,567 (18752, 20410)	0.57 (0.55, 0.60)	20,891 (20340, 21422)	0.65 (0.64, 0.67)

Longitudinal trends in pairwise inequality from 2015 through 2020 showed differing trends in SIM rate inequality between races within low and high MDI terciles. In tercile 1, SIM rate inequality was higher for AIANs versus other races but the inequality metrics did not fluctuate significantly. Comparing Whites to Blacks, there were not significant changes in the relative inequality in rate ratio or PAR, but the number of excess cases among Whites increased significantly. From 2015 to 2020 for SIM rate inequality in tercile 3, metrics changed significantly over the study period comparing AIANs to both other races, inequality peaked between 2017 and 2018. Differences in SIM rate between Whites and Blacks in tercile 3 decreased significantly over the study period, as SIM rates for Blacks rose faster than for White leading to a significant decrease in SIM rate inequality between these two groups.

Substance-Involved SIM Deaths and MDI

Several methods were used to analyze the relationship between substance-involved SIM and MDI. This included linear and logistic regression approaches.

ANOVA

A one-way ANOVA determined that there were significant differences between the general SIM rates across MDI level terciles, $F(2,141) = 3.77$, $p < 0.05$, $\eta^2 = .13$, and quartiles, $F(2,141) = 4.80$, $p < 0.05$, $\eta^2 = 0.18$) (i.e., main effect of MDI). A Tukey post hoc test revealed the mortality rate was significantly higher in the highest MDI tercile (*M* = 23.9, 95%CI: 22.3, 25.7) compared to the lowest tercile (*M* = 20.4, 95%CI: 18.7, 22.2). Similar findings were identified in a separate ANOVA analysis of MDI rates by quartile. Post hoc tests for this analysis showed that the SIM rates in the highest MDI quartile (*M* = 25.0, 95%CI: 23.0, 27.2) were significantly higher than all other quartiles, which did not differ significantly from each other. A relatively strong regional effect on mortality rate was also identified ($F(3,140) = 2.60$, $p < 0.05$, $\eta^2 = .58$). Notably, in ANCOVA analyses for SIM rate on MDI groups that controlled for region, there were no significant differences across terciles, but the significant differences across quartiles were maintained ($F(3,139) = 3.03$, $p < .05$, $\eta^2 = .61$).

Alcohol-related mortality rates took on a different distribution than other subsets and violated ANOVA assumptions when using MDI quartiles. Analyses with MDI terciles indicated no significant differences in alcohol-related mortality rate across levels of MDI in the omnibus ANOVA test. However, two-way ANOVAs showed there was a significant interaction between MDI and region; in the ANCOVA test controlling for region the effects were no longer significant.

Separate one-way ANOVA models on drug-related mortality rates revealed significant differences SIM rates across MDI quartiles ($F(3,140) = 3.10$, $p < 0.05$, $\eta^2 = 0.14$), but not terciles. For MDI rate quartiles, the mortality rates for the lowest and highest quartiles were not significantly different. Consistent with the pattern of results for overall SIM rates, two-way ANOVAs revealed there was a significant interaction between MDI group and region for both MDI terciles and quartiles. Controlling for region, there was a significant main effect of MDI group for both terciles, ($F(2,140) = 5.91$, $p < 0.05$, $\eta^2 = .09$) and quartiles ($F(3,139) = 6.60$, $p < .05$, $\eta^2 = .12$). As in the omnibus model for MDI quartiles, there was no significant difference between mortality rates in the lowest and highest quartiles.

Linear Regression

Regression models were also completed for the relationship between substance-involved SIM rate and MDI. Each modeled the substance-specific SIM rate for each state-year observation (i.e., the outcome was alcohol-related SIM rate, drug-related SIM rate, or alcohol- and drug-related SIM rate). The relationship was best modeled with a quadratic function for each type of substance-involved death as the slope changed based as values increased. The models estimated were as follows:

$$SIMR\widehat{ate_{Substance_{\iota}}} = \widehat{\beta_0} + \beta_1\widehat{MDI}_{\iota} + \beta_2\widehat{MDI}_{\iota}^{\,2}$$

Figure 18. Age-Standardized State-Year SIM Rate and State-Year MDI by Substance Use Involvement, 2015-2020.

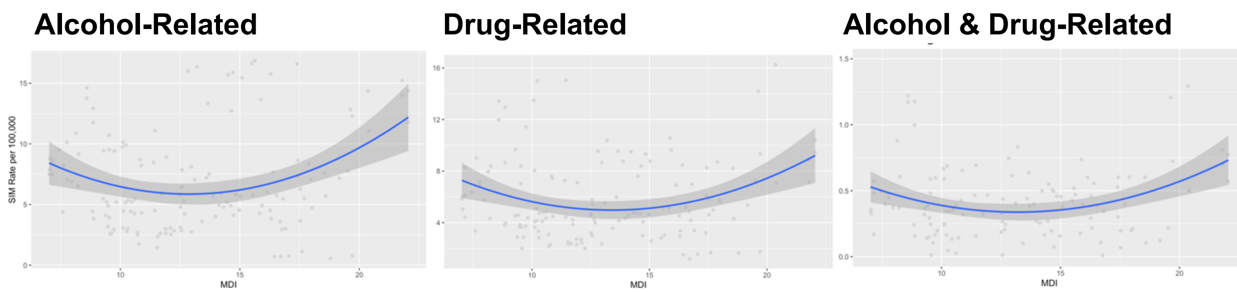


Figure 18 shows the modeled trend in the relationship between SIM rate and MDI for each substance involved death type with 95%CIs. The magnitude of the curvature was most apparent for alcohol-related deaths, whereas the curve for deaths involving drugs was flatter. The coefficients in each model were significant, with the positive quadratic term indicating that higher deprivation levels were associated with a higher substance-involved SIM rate at higher levels of MDI. Still, the relationship was opposite at the lowest levels of MDI. Accordingly, when the MDI values are mean-centered, the first-order coefficient is no longer significant; this suggests the relationship between substance-involved SIM rate and MDI is positive at values above mean MDI.

Logistic Regression

Logistic regressions and associated predicted probabilities estimated the relative probability-based outcome of substance-involved SIM deaths. Separate models were estimated predicting alcohol-related, drug-related, and alcohol and drug-related deaths (no/yes) from MDI and race. A model was estimated with race alone (base model), and a second model included an interaction term for race and MDI (interaction model).

$$\widehat{p_{BaseModel}} = logit(P(Substance = \widehat{Yes}|MDI, Race = White) = \frac{exp(\widehat{\beta_0} + \widehat{\beta_1 MDI} + \widehat{\beta_2 Race})}{1 + exp(\widehat{\beta_0} + \widehat{\beta_1 MDI} + \widehat{\beta_2 Race})})$$

$$\widehat{p_{InteractionModel}} = logit(P(\widehat{Substance} = Yes|MDI, Race = White) = \frac{exp(\widehat{\beta_0} + \widehat{\beta_1 MDI} + \widehat{\beta_2 Race} + \beta_3 \widehat{MDI \times Race})}{1 + exp(\widehat{\beta_0} + \widehat{\beta_1 MDI} + \widehat{\beta_2 Race} + \beta_3 MDI \times Race)})$$

Predicted probabilities were estimated for mean MDI by race for each type of substance-involved death. Trends in predicted probabilities of substance-involvement by MDI for each race are presented in figure 10. The overall predicted probability of a substance-involved death at mean MDI was highest for AIANs for alcohol only ($p_{\widehat{AlcoholAIAN}}$=0.54) and alcohol and drug-related deaths ($p_{\widehat{AlcoholDrugsAIAN}}$=0.16), but not for drug-related deaths ($p_{\widehat{DrugsAIAN}}$= 0.32). The predicted probability at mean MDI was highest for drug-related deaths among Whites ($p_{\widehat{DrugsWhite}}$ = 0.35, $p_{\widehat{AlcoholWhite}}$=0.51, $p_{\widehat{AlcoholDrugsWhite}}$ = 0.10). Predicted probabilities were lowest for Blacks for each type of substance involvement ($p_{\widehat{AlcoholBlack}}$ =0.47, $p_{\widehat{DrugsBlack}}$ =0.28., $p_{\widehat{AlcoholDrugsBlack}}$ =0.09).

Figure 10. Predicted Probability of Substance-use Involved Death by Race.

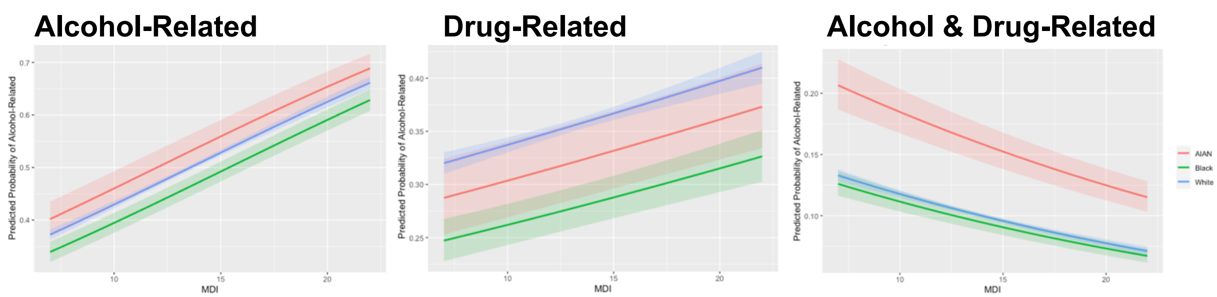


Table 6 shows the regression output with odds ratios (OR) for the two logistic regression models predicting the relative odds of a substance-involved death from MDI. The interpretation of the base model coefficients is the change in SIM rate associated with a 1 unit increase in MDI, which translates to a 1 percentage point increase in the percent of the population that is multidimensionally deprived (e.g., an increase in MDI from 10% to 11%). A 1 unit increase in MDI was associated with an increase in the relative odds of a death involving substance use for alcohol-only and drug-only deaths ($p<0.05$). Interestingly, the relationship was the opposite for deaths involving both alcohol and drugs.

For the base model on alcohol-related deaths, holding race constant, there was an 8% increase in the odds of an alcohol-related death associated with a 1 unit increase in MDI. Considering race, there was no significant difference in the relative odds of an alcohol-related death for Whites and AIANs; however, holding MDI constant, Blacks had significantly lower odds of an alcohol-related death relative to Whites. The base model results predicting the odds of a drug-related death followed a similar pattern. There was a 3% increase in the relative odds of a drug-related death associated with a 1 percentage point increase in MDI, holding race constant. There was no significant difference in the odds of a drug-related death for AIANs and Whites, but the odds were lower for Blacks relative to Whites. Finally, for deaths involving both drugs and alcohol, holding race constant, the relative odds decreased by 5% for a unit increase in MDI. However, holding MDI constant, the odds of a drug and alcohol-related death were 70% higher for AIANs compared to Whites; there was no significant difference between Blacks and Whites.

The interaction models include an interaction term for MDI and race. This term is included to describe potential differences in the relative effect of MDI on SIM rate by race. Due to the presence of the interaction term, the main effect coefficients are no longer interpreted as the change in SIM rate associated with a 1 unit increase in MDI, holding the other variables constant. For alcohol-related deaths, a 1 percentage point increase in MDI is associated with an 8% (i.e., $OR_{White} = \exp(\beta_{MDI})$) increase in odds for Whites, and a 14% (i.e., $OR_{Black} = \exp(\beta_{MDI} + \beta_{MDI*Black})$) increase in odds for Blacks relative to Whites. Among AIANs, a unit increase in MDI is associated with a 1% (i.e., $OR_{AIAN} = \exp(\beta_{MDI} + \beta_{MDI*AIAN}$) decrease in odds of an alcohol-related death compared to Whites.

For drug-related deaths, a 1 percentage point increase in MDI was associated with a 3% increase in odds for Whites, and a 4% decrease in odds for AIANs compared to Whites. There was no significant difference between Blacks and Whites. Among deaths that involved both alcohol and drugs, there was no significant interactive effect for race and MDI. However, a unit increase in MDI was associated with a 5% decrease in the relative odds of a death involving alcohol and drugs for Whites.

Table 11. Regression Models for Substance-Involved SIM rate on MDI and Race with Odds Ratios (OR)						
	Base Model			Interaction Model		
Effect	Estimate (OR)	SE	p	Estimate (OR)	SE	p
Alcohol						
Intercept	1.03	1.01	<.05	0.34	1.04	<.05
MDI	1.08	1.00	<.05	1.08	1.00	<.05
Race						
White	ref			ref		
AIAN	1.13	1.06	.06	4.78	1.32	<.05
Black	0.87	1.04	<.05	0.38	1.23	<.05
MDI x Race						
AIAN				0.91	1.01	<0.05
Black				1.06	1.01	<0.05
Drug						
Intercept	0.551	1.01	<.05	0.39	1.04	<0.05
MDI	1.03	1.00	<.05	1.03	1.00	<0.05
Race						<0.05
White	ref			ref		
AIAN	0.86	1.09	.07	2.36	1.44	<0.05
Black	0.70	1.05	<.05	0.53	1.26	<0.05
MDI x Race						
AIAN				0.94	1.02	<0.05
Black				1.02	1.01	.24
Alcohol and Drug						
Intercept	0.11	1.01	<.05	0.21	1.04	<0.05
MDI	0.95	1.00	<.05	0.95	1.00	<0.05
Race						
White	ref					
AIAN	1.70	1.06	<.05	1.06	1.28	.79
Black	0.94	1.04	.15	1.18	1.23	.41
MDI x Race						
AIAN				1.03	1.01	.05
Black				0.98	1.01	.26

Summary of Stage 1 and 2 Results

SIM rates were highest among AIAN decedents and lowest among Black decedents. The magnitude of increase in SIM rate was greatest for Black decedents. Significant SIM rate increases among AIAN and Black subjects were primarily attributable to increases in younger age groups.

Overall, the MDI of many states varied over time, and there were significant differences in MDI between states. A higher proportion of deaths among AIANs occurred at higher MDI levels, and a higher proportion of deaths among Whites occurred at lower MDI levels. There were more deaths in high versus low MDI states for both AIANs and Blacks but not for Whites.

The curvilinear relationship between SIM and MDI suggests that the slope of the relationship between SIM and MDI increases faster at higher levels of deprivation. The quadratic relationship was also present in alcohol-related and drug-related deaths. An increasing percent of the population multidimensionally deprived (i.e., increasing MDI) was associated with increased relative odds of an alcohol- or drug-related SIM death. This relationship also varied across racial groups in some cases. The rates among Blacks were significantly lower across all types of substance-involved SIM deaths. Alcohol-related deaths were significantly more common across all levels of MDI for AIANs versus other groups, but, holding MDI constant, the relative odds were not significantly different compared to Whites. However, the naturally hierarchical nature of the data—individuals nested within state-years, nested within regions—and the identified regional clustering of MDI suggest that multi-level modeling of the relationship between SIM and MDI is warranted.

Stage 3: Multi-level Modeling

Three multi-level models were used to predict SIM rate from MDI, nested within state. Model 1 is a random intercepts only model, allowing the intercepts to differ by state. Model 2 is a mixed random effects model with both random intercepts and random slopes, allowing for both the intercepts and coefficients to potentially differ by state. Random slopes allow the relationship between MDI and SIM rate to be unique to each state. Model 3 is the same as model 2, but controls for year by adding it as a fixed effect predictor.

Overall multi-level modeling results suggest significant variation in SIM rate by state. The Interclass correlation (ICC) for the null model ($\widehat{\rho_{null}} = 0.33$)—which considered only clustering by state with no predictors—suggested a relatively large share of the total variation in state-year

SIM rate is associated with state. This contrasts with ICC values for clustering within year, which was almost 0. When the data were subset into observations that were below and above Median MDI, the estimated ICC was higher for low MDI ($\widehat{\rho_{LowMDI}} = 0.40$)versus high MDI ($\widehat{\rho_{HighMDI}} = 0.30$.

Model estimates are shown in table 12. Model 1 results show that the fixed effect of MDI was not significant. However, the random effects were all significant. The intercept random effect estimate indicated significant variation from one state to another, even after accounting for MDI. The estimated residual is relatively large, suggesting there was also significant within-state variation in SIM rates.

In model 2, the fixed effect estimates were maintained from model 1. The random effects also continued to indicate that there was significant variation the intercept across states, and those estimates were not significantly different than in model 1. The random effect for MDI implied significant variation in the coefficients across states; thus, the relationship between SIM rate and MDI varied significantly across states. The random effect for MDI was more than six times larger than the intercept estimate and about twice as large as the residual. This showed that the largest source of variation in SIM rate was due to the differing effect of MDI on SIM across states. In model 3 the trends in the fixed and random effect relationships were maintained, even after controlling for the fixed effect of year.

Table 12. Multi-level Modeling Estimates of SIM rate and MDI from Random Intercept Only and Random Slopes Models.

Model 1 Random Intercepts			**Model 2 Random Slopes**			**Model 3 Random Slopes plus Year**		
Fixed								
	Estimate	**95% CI**		**Estimate**	**95% CI**		**Estimate**	**95% CI**
Intercept	-8.42	-8.60, -8.24	**Intercept**	-8.50	-8.70, -8.23	**Intercept**	-8.40	-8.66, -8.11
MDI	-0.15	-1.15, 0.86	**MDI**	0.24	-1.40, 1.83	**MDI**	-0.30	-2.20, 1.60
						Year	-0.003	-0.01, 0.003
Random								

	Estimate	95% CI		Estimate	95% CI		Estimate	95% CI
Intercept	0.29	0.22, 0.40	**Intercept**	0.43	0.26, 0.72	**Intercept**	0.43	0.26, 0.72
Residual	1.46		**MDI**	2.70	1.54, 4.70	**MDI**	2.73	1.60, 4.71
			Residual	1.30		**Residual**	1.27	

CHATPER 5: DISCUSSION

This chapter begins by presenting findings and the contextualization of those findings within the existing body of research. It then discusses the study's limitations, opportunities for future research, and finally presents conclusions.

Highlights of Primary Findings

In summary, empirical linkages were identified between MDI and SIM risk at the state-year level. Evidence suggests a dose-response relationship between SIM rate and MDI, where the effect of MDI on SIM rate may be most potent above mean MDI. This trajectory generally held in models that accounted for observations being nested within states. Findings also suggest significant racial disparities across SIM rates that were significantly influenced by deprivation level. The odds of alcohol-related and drug-related SIM was increased as MDI increased, but the racial inequity in risk remained relatively constant.

Highlights of Findings on SIM Decedent Characteristics

Findings on decedent characteristics showed that a substantial portion of SIM decedents had lower education levels (less than 50% had a college degree). Manufacturing, construction, and labor market non-participation were also relatively common. This aligns with similar research findings, which highlight the association between suicide and substance-involved deaths with economic factors such as occupation type and quality and macroeconomic trends that influence the manufacturing sector (Autor et al., 2019; Default et al., 2022; Gutin & Hummer, 2020; Hawkins et al., 2020; Monnat, 2019; Prins et al., 2018; Pierce & Shott, 2020; Rockett et al., 2022; Venkartarmani & Tsai, 2020). It is also supported by findings from deaths of despair literature which underscores the increased vulnerability to suicide, alcohol-, and drug-related deaths among those with less than a bachelor's degree (Case & Deaton, 2021). In addition, a significantly higher proportion of AIANs and Blacks, versus Whites, had lower education, which may reflect younger age groups represented among decedents of color; however, it may also contribute to heightened vulnerability among these groups.

Highlights of Findings on MDI

The variation in MDI within and between states clustered by region is an expected pattern, as states that are physically closer together (i.e., within the same region) would reasonably share more similarities in factors that influence what percent of the population lives in deprivation. This suggests that additional factors connecting geographically proximal states could be implicated in the relationship between socio-economic context and SIM risk.

The inequitable distribution of deprivation across races points to the differential systemic effects of contextual socio-economic factors. There was a gradient of potential exposure to contextual-level deprivation, with AIANs having the highest level of exposure, followed by Blacks, then Whites. Though AIANs have the highest percent living in deprivation and the highest SIM rates, Whites have the lowest levels of deprivation and have the second-highest SIM rates. This implies heterogeneity in the White population where additional factors (e.g., education) among Whites could influence risk beyond the tendency to live in less deprived communities. For example, low socio-economic status Whites living in relatively well-off communities could be at increased risk of SIM compared to their neighbors with a higher social status. This observation fits well within the deaths of despair framework, which posits increased risk for "disadvantaged Whites."

Highlights of Findings on SIM Rates

Overall, SIM rates followed the expected pattern based on trends in suicide. AIANs experience the highest burden of SIM, followed by Whites and Blacks. Cumulatively over the study period, the percent change in SIM rate increased for AIANs and Blacks but not for Whites, and there was a significant year-to-year increase in the rate of change in SIM rate for Blacks.

Increases in SIM rates for AIANs and Blacks were primarily attributable to increases in younger age groups. The trend among Black decedents is especially alarming, considering there were increases in both the rate of change and the overall SIM rate. Previous research has established that SIM-related death risk is highest for younger AIANs. Thus, it is also alarming to note that SIM rates increased over the study period for younger adult AIANs.

Highlights of Findings on Substance-Involved SIM

As expected, a significant portion of the deaths involved alcohol and/or drugs. However, an almost equal portion (about one-fifth) involved only drugs and both alcohol and drugs. This points to the potentially salient interactive impact of alcohol and drugs on SIM risk. In addition, racial differences in alcohol- versus drug involvement suggest potentially differential risks across races. Keeping with previous research, AIANs had significantly higher rates of alcohol-related deaths and deaths involving both alcohol and drugs. These findings support current clinical efforts that encourage the integration of substance abuse into suicide prevention and mental health treatment among AIANs. Considering this sample also includes deaths of undetermined intent, it could suggest that suicide prevention should be integrated into substance abuse treatment.

There was no significant difference in the relative odds of drug-related deaths for AIANs versus Whites, but the rate for Whites was higher. This could reflect a true increased risk in drug-involved SIM among Whites versus AIANs and Blacks. This would follow research findings on the opioid epidemic, suggesting White Americans, especially those in rural areas with disadvantaged socio-economic status, are at increased risk of drug-related deaths, especially opioids (e.g., Altekruse et al., 2020; Dasgupta et al., 2018; Monnat, 2018; Pear et al., 2019). However, this finding could also reflect testing biases related to race or the higher availability of toxicology resources in states with lower deprivation levels—in which Whites are overrepresented. Essentially, this could mean that Whites have higher drug testing rates because they live in areas with better medicolegal infrastructure to conduct high-quality death investigations that include standard toxicology. Results from the predicted probability of deaths involving both drugs and alcohol across MDI levels may support this assertion. The trend showed that the odds of a death being drug and alcohol-related decreased as MDI increased, which could reflect testing resources.

Highlights of Findings on SIM rates and MDI

The SIM decedent sample distribution within MDI levels followed a somewhat expected pattern, with AIANs having higher rates at low and high MDI, followed by Whites and Blacks, respectively. Differences in the distribution of SIM deaths by race across MDI levels may be a product of multiple factors, including population composition and the nature of the relationship between SIM and MDI. For example, lower MDI states may contain a larger White population (e.g., Northeast states have a high percent White population and lower MDI levels). Thus, the effect of state-level MDI on SIM rate may be particularly salient when a higher proportion of the population lives in deprivation. This is consistent with previous research findings that lower-income and higher poverty rates are generally associated with an increased risk of SIM-related outcomes (Phillips, 2013; Zeglin et al., 2020).

The SIM rate was significantly higher in areas with the highest deprivation levels than those with the lowest levels. This means that states with a higher proportion of the population deprived on at least two MDI dimensions also have higher SIM rates. Findings from comparisons of how the relationship between MDI and SIM rate changed at the beginning and end of the study suggest that states with MDI that was higher in 2020 compared to 2015 also had increasing SIM rates between the two years. This is consistent with research showing that suicide rates are increasing but implicates state-level socio-economic factors as a potential driver of SIM risk (NASEM, 2021). This effect may be due to a higher risk conferred among individuals experiencing deprivation or due to a contextual effect. Contextually, the exposure to others living in deprivation or structural factors that cause higher deprivation may confer risk independently or in combination with individual-level exposure.

The disparity in SIM rates between the lowest and highest MDI areas also increased over the study period. The racial disparity in SIM was also greater in lower MDI versus higher MDI, suggesting that the racial differences between SIM rates are higher at the lowest level of MDI compared to the highest. However, this is primarily accounted for by AIANs and Whites having more similar rates, though the largest (and significant) increases in SIM rates occurred among Blacks at the highest levels of deprivation.

While higher overall SIM rates at high levels of deprivation suggest a heightened risk associated with living in a high deprivation state, the magnitude of increase in SIM rate at high MDI is especially apparent for Whites. Higher racial inequality at higher levels of deprivation suggests that state-level socio-economic factors measured by the MDI may contribute to SIM risk, especially among Whites. It is possible that socio-economic factors affect Whites more potently in areas with higher levels of deprivation or that contextual socio-economic factors are a more potent risk factor for Whites versus AIANs and Blacks.

The curvilinear relationship between state-year SIM rate and MDI was present in single-level and multi-level models, suggesting a dose-response relationship. At lower levels of MDI, contextual level deprivation may not meaningfully increase SIM risk. However, once state-level MDI reaches a certain threshold (around mean MDI, 13%), MDI begins to be associated with higher SIM rates. Curvilinear relationships were also seen for substance-involved deaths, though to a lesser magnitude than for all SIM deaths.

Many potential explanations exist for the observed trajectory of the relationship between SIM rate and MDI. First, the SIM risk conferred by state-level MDI could be constant. In that case, the effect could be explained simply by the difference between the large gap in the population at risk in the lowest MDI states (e.g., in quartile 1 MDI ranged 7%-11%) compared to the highest MDI states (e.g., in quartile 4 MDI ranged 17%-22%). However, multi-level modeling results indicate that the relationship varies across states and that the effect of MDI on SIM is much greater than the overall effect of state on SIM rate. Thus, the effect of MDI on SIM rate may be more similar among groups of states; for example, single-level results also indicated a robust regional effect, and states within region tended to have more similar MDI levels. The effect of MDI on SIM among states with lower MDI may be less potent, whereas the effect may be substantial at higher levels. If these are grouped by region, it may suggest a contagion effect, where low MDI states associated with low SIM risk provide some protective effect to their neighboring states and vice versa. There is precedent for an area-based contagion effect in studies of county-level suicide rates and drug overdose deaths; thus, this may extend to socio-economic factors and SIM deaths (Kandula et al., 2023; Steelsmith et al., 2019; Sy et al., 2019).

Since the MDI measure is calculated as the percent of the population living deprived on at least two dimensions, high MDI states may also be comprised of a higher percent of the population living at higher magnitudes of deprivation (e.g., deprived on many dimensions) with the opposite trend among low MDI states (e.g., deprived on only two dimensions). In this case, the MDI would only capture a partial effect of the socio-economic environment on SIM risk. The proportion of people living in MDI-defined deprivation who are deprived on all dimensions may comprise a constant proportion of the MDI population, or that may fluctuate based on individual states or the total percent living in deprivation. Essentially, the population deprived in low MDI states may receive a small “dose” of deprivation (i.e., deprived on only two dimensions) versus those in high MDI states who may receive a larger “dose” (i.e., deprived on many dimensions). Thus, the magnitude of the effect captured by MDI could be higher in high MDI states because the deprived individuals in those states are living with more types of deprivation than individuals living in deprivation in low MDI states.

Single-level results are supported by those from multi-level modeling, which considered the potentially different effects across states. Multi-level findings indicate that baseline SIM rates differed across states, and the SIM rate at 0% MDI would also be significantly different across states. Notably, the relationship between SIM rate and MDI differed across states. This suggests that the effect of MDI on SIM is not the same across all states. Together with single-level results, multi-level findings highlight that the state environment in which a person lives has the potential to significantly influence SIM risk and that the potential increased risk associated with higher state-year MDI is also impacted by state of residence.

Many potential factors could influence differences in the effect of MDI on SIM rate across states. Other clustering factors, such as region, may play a role. Several state-level factors are also known to influence SIM risk that could be related to MDI and mitigate or heighten the associated risk. For example, state-level earned income tax credit and minimum wage policies are associated with suicide risk (Gertner et al., 2019). Protective or risk-enhancing policies may also take on a regional effect, where areas like the northeast may be more likely to have more liberal social welfare policies that help mitigate SIM risk associated with MDI.

Limitations

This study has several limitations. As noted, this study's applied definition of SIM deaths only represents some of what is included in the conceptual definition. Specifically, this study did not investigate unintentional drug overdose deaths. While this is an opportunity for future research, focusing on only suicides and deaths of undetermined intent may be beneficial because it represents more homogeneous acts of self-injury.

Furthermore, this analysis did not include covariates that could influence SIM rates or moderate the relationship between MDI and SIM at the contextual level, such as population density, firearm availability, or state policies. Because of sample size limitations, race-specific estimates could not be made for all states in all years, and where estimates were made, some may be unreliable if based on death counts of less than 20. It is also important to note that the data used were collected from only some states and only from 2015 through 2020. Multi-level modeling was limited by non-convergence for longitudinal models that included random effects for both state and year. Thus, the results may not be generalizable to all states or all years or accurately account for year effects.

Due to constraints on individuals and record-keeping systems during the pandemic in 2020, data for that year may be unreliable. For example, the U.S. Census (2022) reports population data collected during 2020 was unreliable. While the quality of NVDRS data is expected to be higher than what occurs on traditional death certificates, it is still subject to error. Conceptual and empirical evidence suggests that suicides overall are likely undercounted due to several factors such as social biases and inadequate infrastructure (Institute of Medicine, 2002). Additionally, SIM rates for AIANs are significantly underestimated due to a high rate of racial misclassification (Arias et al., 2021). The CDC estimates that 40% of non-Hispanic AIAN decedents had their race misclassified on death certificates (Arias et al., 2016). In the context of this study's results, SIM rates among AIANs are likely significantly higher than reported here.

NVDRS data are also limited by what information is collected at the local level. Not all necessary information about factors that precipitated the deaths may be available, and that information is subject to inaccurate reporting. Potential misreporting is a risk for substance-involved deaths. Furthermore, the CDC does not fund toxicology in all states; thus, testing is not uniform across localities. The collection of toxicology data is under the purview of medical examiners/coroners in charge of managing mortality data for each area. Testing may depend upon funding from the CDC or elsewhere. For substance-involved deaths, it is impossible to differentiate between cases where information is missing, "unknown," or "not applicable." Thus, there are likely cases where substance involvement was suspected, but toxicology testing was not completed at the direction of the coroner/medical examiner or due to lack of funds. Some studies suggest that the type of medicolegal system in place (i.e., if an area has a coroner versus a medical examiner) can also influence the quality of data collected (Denham et al., 2022; Institute of Medicine, 2002). Medical examiners tend to have higher expertise levels than coroners, which are often elected positions (Institute of Medicine, 2002).

It is also possible that recording a death as substance-involved is biased based on human factors and county or state-level characteristics. For example, the likelihood of completing toxicology testing could be influenced by the coroner/medical examiner's experiences or the prevalence of substance use in a given community. These factors could also affect the availability of funding to conduct toxicologic testing.

The MDI is a composite measure that includes multiple social and economic deprivation indicators. However, this study did not investigate the relative contributions of those dimensions. Using the MDI as a composite measure of deprivation at the state level may not accurately represent area-based deprivation, or it may mask heterogeneity in the relative contribution of specific types of deprivation. MDI from smaller geographical subsets (i.e., counties) likely has a more substantial influence on SIM compared to MDI measured at the state level.

Future research

Future research is needed to further our understanding of the relationship between contextual socio-economic deprivation and SIM rates. New research should address limitations in data, methodology, and unanswered questions implicated by preliminary findings such as those presented in this study. Some limitations can be addressed by creating a sample of SIM decedents that includes unintentional drug deaths and exploring if the association between MDI and SIM rates holds. Adding additional deaths to form a more comprehensive SIM definition will increase the sample size, potentially enough to allow for race specific-estimation of multi-level and other race-specific models.

Future analytical approaches to research the impact of socio-economic context on SIM should fit longitudinal multi-level models that account for the effect of year. These, and other analyses, should also consider adding additional variables that could help elucidate the impact of state, county, and individual-level factors. Policy variables could play an important role if they significantly impact SIM rates; this provides actionable evidence to policymakers suggesting ways to address SIM at a population level meaningfully. Policies conceptually related to MDI and SIM rates may be essential levers (e.g., social welfare programs, neoliberal trade policies, and healthcare).

Single-level analyses of the impact of MDI on SIM rates alone could be helpful. County-based socio-economic indicators would likely have a more substantial impact, as the effects are more proximal versus state-level MDI. It may also be helpful to differentiate between individual and county-level socio-economic factors to determine the relative impact of the environment versus individual experiences. Extrapolating from other research on suicide and opioid deaths (e.g., Monnat, 2019; Steelsmith et al., 2019), contrasting areas with both high deprivation and high suicide rates with areas with low metrics for both could highlight risk and protective factors. This may also help elucidate how the relationship between SIM and MDI differs across geographical areas.

Finally, as suggested by the NASEM report on high and rising mortality among working-age Americans, there is a great need for research focusing on racial disparities in suicide, alcohol-, and drug-related deaths and how these may be related to socio-economic contextual factors (NASEM, 2021). Among Blacks, the alarming increase in SIM rate concentrated among youth echoes longstanding patterns in mortality composition among AIANs and should be an immediate focus of research and intervention efforts. For AIANs, analyses focused on areas with high AIAN populations may be useful.

Conclusions

This study investigated the effect of state-level socio-economic deprivation on SIM rates and differences in vulnerability to SIM across races. Though existing research establishes links between socio-economic circumstances and SIM-related outcomes, research on SIM outcomes rarely incorporates contextual-level factors. Fewer studies incorporate race, especially AIANs. This study was conducted in response to this gap and to answer the call for research on factors associated with racial disparities in SIM-related deaths. Therefore, this study's findings add much-needed information to a growing body of research. Findings here help elucidate how contextual socio-economic deprivation impacts risk for SIM and substance-involved SIM and how that risk may differ between AIAN, Black, and White Americans.

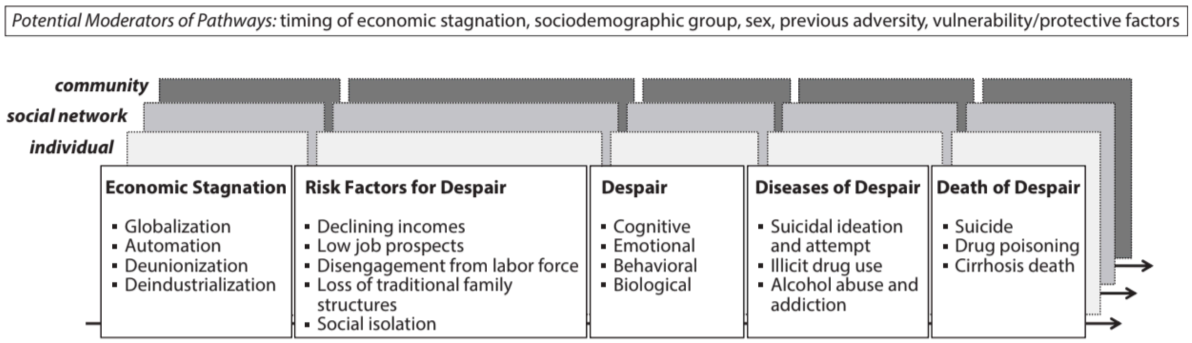
Results have implications for policymakers, public health officials, and clinical guidelines; they also raise questions for future research. The finding that the magnitude of SIM rate increases is greater at high levels of deprivation suggests two potential avenues for intervention and prevention efforts. First, efforts that concentrate on mitigating challenges posed by deprivation experiences may promise to effectively decrease SIM risk at a population level. This could include approaches such as strengthening social welfare programs. Second, socio-economic support-based efforts may need to be concentrated in states with larger populations that experience multidimensional deprivation. Alcohol-related and drug-related SIM rates also increased as MDI increased. This could be addressed by targeting substance abuse interventions and prevention efforts in high MDI areas, some of which should incorporate suicide prevention.

Findings support the conceptual arguments within the “deaths of despair” framework. Significant racial disparities in SIM rates across all levels of MDI raise questions about the impact of concentrated socio-economic deprivation. However, racial disparities in SIM are smaller at the highest levels of deprivation, especially as rates are particularly elevated for Whites in high deprivation settings. Future work should critically evaluate the mechanisms of potential increased vulnerability to socio-economic stressors across racial groups in low versus high deprivation areas.

Overall, this study highlights how the social and economic contexts in which people live can meaningfully impact the risk of self-directed harms. It provides evidence for a more holistic and less psycho-centric understanding of SIM risk. Identifying the potential role of MDI in SIM risk suggests multiple common upstream factors that could be translated into prevention efforts that could target multiple SIM-related outcomes while also avoiding blaming individuals. Taking a contextual-level approach fits well with policy interventions that could be implemented at the state level and potentially decrease population-level risk exposure and decrease SIM risk for all people.

APPENDIX A. CONCEPTUAL MODELS

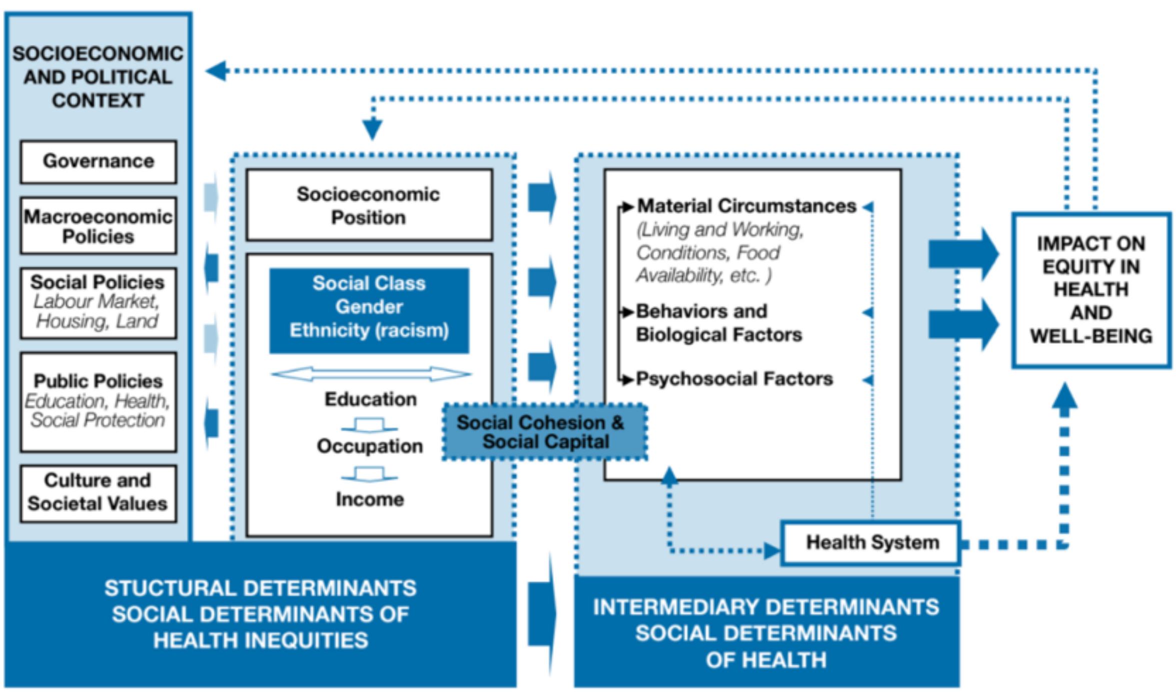
Appendix Figure A1. The conceptual model for “deaths of despair” (Shanahan et al., 2019).



Shanahan et al., 2019

FIGURE 1—Hypothesized Developmental Progression From Economic Stagnation to Deaths of Despair

Appendix Figure A2. The Social Determinants of Health Conceptual Framework from the World Health Organization’s Commission on Social Determinants of Health (Solar & Irwin, 2010).



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